

CHAPTER 6

REFRIGERATION

Learning Objective: Describe the stages of heat theory and the principles involved in heat transfer, and recognize various components of refrigeration systems and their application. Recognize the characteristics and procedures required to service and troubleshoot refrigeration systems.

Modern refrigeration has many applications, such as preserving medicine, blood, and the most important application, the preservation of food. Most foods kept at room temperature spoil rapidly. This is due to the rapid growth of bacteria. Refrigeration preserves food by keeping it cold, which greatly slows down the growth of bacteria. In days past, blocks of ice were used in iceboxes to refrigerate food and other items. These iceboxes were small and not very practical. Today, mechanical refrigeration systems make transportation, storage, and use of refrigerated goods easy and practical.

The installation, operation, adjustment, and repair of refrigeration equipment are the primary responsibility of the Utilitiesman rating. To perform these duties required of a refrigeration mechanic, you need to understand the principles and theory of refrigeration and recognize system components and understand the way they work within the system.

Methods of installing, maintaining, and repairing refrigeration equipment and maintaining, servicing, and repairing domestic refrigerators and freezers are also covered in this chapter.

HEAT AND REFRIGERATION PRINCIPLES

Learning Objective: Explain the basics of heat theory and the basic principles of refrigeration.

REFRIGERATION is the process of removing heat from an area or a substance and is usually done by an artificial means of lowering the temperature, such as the use of ice or mechanical refrigeration. MECHANICAL REFRIGERATION is defined as a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another. Since refrigeration deals entirely with the removal or transfer

of heat, some knowledge of the nature and effects of heat is necessary for a clear understanding of the subject.

NATURE OF HEAT

Heat is a form of energy contained to some extent in every substance on earth. All known elements are made up of very small particles, known as atoms, which, when joined together, form molecules. These molecules are particular to the form they represent. For example, carbon and hydrogen in certain combinations form sugar and in others form alcohol.

Molecules are in a constant state of motion. Heat is a form of molecular energy that results from the motion of these molecules. The temperature of the molecules dictates to a degree the molecular activity within a substance. For this reason, substances exist in three different states or forms—solid, liquid, and gas. Water, for example, may exist in any one of these states. As ice, it is a solid; as water, it is a liquid; and as steam, it is a gas (vapor).

When heat is added to a substance, the rate of molecular motion increases, causing the substance to change from a solid to a liquid, and then to a gas (vapor). For example, in a cube of ice, molecular motion is slow, but as heat is added, molecular activity increases, changing the solid "ice" to a liquid "water" (fig. 6-1). Further application of heat forces the molecules to greater separation and speeds up their motion so that the water changes to steam. The steam formed no longer has a definite volume, such as a solid or liquid has, but expands and fills whatever space is provided for it.

Heat cannot be destroyed or lost. However, it can be transferred from one body or substance to another or to another form of energy. Since heat is not in itself a substance, it can best be considered in relation to its

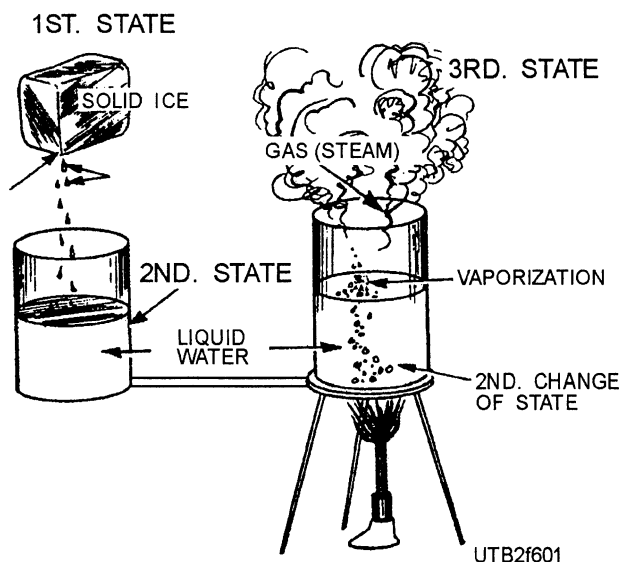


Figure 6-1.—The three states of matter.

effect on substances or bodies. When a body or substance is stated to be cold, the heat that it contains is less concentrated or less intense than the heat in some warmer body or substance used for comparison.

UNITS OF HEAT

In the theory of heat, the speed of the molecules indicates the temperature or intensity of heat, while the number of molecules of a substance indicates the quantity of heat.

The intensity and quantity of heat may be explained in the following simple way. The water in a quart jar and in a 10-gallon container may have the same intensity or temperature, but the quantity of heat required to raise these amounts of water to a higher uniform temperature (from their present uniform temperature) will differ greatly. The 10 gallons of water will absorb a greater amount of heat than the quart jar of water.

The amount of heat added to, or subtracted from, a body can best be measured by the rise or fall in temperature of a known weight of a substance. The standard unit of heat measure is the amount of heat necessary to raise the temperature of 1 pound of water 1°F at sea level when the water temperature is between 32°F and 212°F. Conversely, it is also the amount of heat that must be extracted to lower by 1°F the temperature of a pound of water between the same temperature limits. This unit of heat is called a British

thermal unit (Btu). The Btu's equivalent in the metric system is the calorie, which is the amount of heat required to raise one gram of water 1° Celsius.

Suppose that the temperature of 2 pounds of water was raised from 35°F to 165°F. To find the number of Btu required to increase the temperature, subtract 35 from 165. This equals a 130° temperature rise for 1 pound of water. Since 2 pounds of water were heated, multiply 130 by 2, which equals 260 Btu required to raise 2 pounds of water from 35°F to 165°F.

MEASUREMENT OF HEAT

The usual means of measuring temperature is a thermometer. It measures the degree or intensity of heat and usually consists of a glass tube with a bulb at the lower portion of the tube that contains mercury, colored alcohol, or a volatile liquid. The nature of these liquids causes them to rise or fall uniformly in the hollow tube with each degree in temperature change. Thermometers are used to calibrate the controls of refrigeration. The two most common thermometer scales are the Fahrenheit and the Celsius.

On the Fahrenheit scale, there is a difference of 180° between freezing (32°) and the boiling point (212°) of water. On the Celsius scale, you have only 100° difference between the same points (0° freezing and 100° boiling point).

Of course, a Celsius reading can be converted to a Fahrenheit reading, or vice versa. This can be expressed in terms of the following formula:

$$F = (C \times 1.8) + 32$$

To change Fahrenheit to a Celsius reading, the terms of the formula are as follows:

$$C = (F - 32) \div 1.8$$

TRANSFER OF HEAT

Heat flows from a substance of higher temperature to bodies of lower temperature in the same manner that water flows down a hill, and like water, it can be raised again to a higher level so that it may repeat its cycle.

When two substances of different temperatures are brought in contact with each other, the heat will immediately flow from the warmer substance to the colder substance. The greater the difference in temperature between the two substances, the faster the heat flow. As the temperature of the substances tends to equalize, the flow of heat slows and stops completely when the temperatures are equalized. This

characteristic is used in refrigeration. The heat of the air, of the lining of the refrigerator, and of the food to be preserved is transferred to a colder substance, called the refrigerant.

Three methods by which heat may be transferred from a warmer substance to a colder substance are conduction, convection, and radiation. These principles are explained in chapter 4 of this TRAMAN.

SPECIFIC HEAT

SPECIFIC HEAT is the ratio between the quantity of heat required to change the temperature of 1 pound of any substance 1°F, as compared to the quantity of heat required to change 1 pound of water 1°F. Specific heat is equal to the number of Btu required to raise the temperature of 1 pound of a substance 1°F. For example, the specific heat of milk is .92, which means that 92 Btu will be needed to raise 100 pounds of milk 1°F. The specific heat of water is 1, by adoption as a standard, and specific heat of another substance (solid, liquid, or gas) is determined experimentally by comparing it to water. Specific heat also expresses the heat-holding capacity of a substance compared to that of water.

A key **RULE** to remember is that .5 Btu of heat is required to raise 1 pound of ice 1°F when the temperature is below 32°F; and .5 Btu of heat is required to raise 1 pound of steam 1°F above the temperature of 212°F.

SENSIBLE HEAT

Heat that is added to, or subtracted from, a substance that changes its temperature but not its physical state is called **SENSIBLE HEAT**. It is the heat that can be indicated on a thermometer. This is the heat human senses also can react to, at least within certain ranges. For example, if a person put their finger into a cup of water, the senses readily tell that person whether it is cold, cool, tepid, hot, or very hot. Sensible heat is applied to a solid, a liquid, or a gas/vapor as indicated on a thermometer. The term *sensible heat* does not apply to the process of conversion from one physical state to another.

LATENT HEAT

LATENT HEAT, or hidden heat, is the term used for the heat absorbed or given off by a substance while it is changing its physical state. When this occurs, the heat given off or absorbed does **NOT** cause a

temperature change in the substance. In other words, sensible heat is the term for heat that affects the temperature of things; latent heat is the term for heat that affects the physical state of things.

To understand the concept of latent heat, you must realize that many substances may exist as solids, as liquids, or as gases, depending primarily upon the temperatures and pressure to which they are subjected. To change a solid to a liquid or a liquid to a gas, **ADD HEAT**; to change a gas to a liquid or a liquid to a solid, **REMOVE HEAT**. Suppose you take an uncovered pan of cold water and put it over a burner. The sensible heat of the water increases and so does the temperature. As you continue adding heat to the water in the pan, the temperature of the water continues to rise until it reaches 212°F. What is happening? The water is now absorbing its latent heat and is changing from a liquid to a vapor. The heat required to change a liquid to a gas (or, the heat that must be removed from a gas to condense it to a liquid) without any change in temperature is known as the **LATENT HEAT OF VAPORIZATION**.

Now suppose you take another pan of cold water and put it in a place where the temperature is below 32°F. The water gradually loses heat to its surroundings, and the temperature of the water drops to 32°F until all the water has changed to ice. While the water is changing to ice, however, it is still losing heat to its surroundings. The heat that must be removed from a substance to change it from a liquid to a solid (or, the heat which must be added to a solid to change it to a liquid) without change in temperature is called the **LATENT HEAT OF FUSION**. Note the amount of heat required to cause a change of state (or the amount of heat given off when a substance changes its state) varies according to the pressure under which the process takes place. Figure 6-2 shows the relationship between sensible heat and latent heat for one substance – water at atmospheric pressure. To raise the temperature of 1 pound of ice from 0°F to 32°F, you must add 16 Btu. To change the pound of ice at 32°F to a pound of water at 32°F, you add 144 Btu (latent heat of fusion). There is no change in temperature while the ice is melting. After the ice is melted, however, the temperature of the water is raised when more heat is applied. When 180 Btu are added, the water boils. To change a pound of water at 212°F to a pound of steam at 212°F, you must add 970 Btu (latent heat of vaporization). After the water is converted to steam at 212°F, the application of additional heat causes a rise in the temperature of the steam. When you add 44 Btu

to the steam at 212°F, the steam is superheated to 300°F.

TOTAL HEAT

TOTAL HEAT is the sum of sensible heat and latent heat. Since measurements of the total heat in a certain weight of a substance cannot be started at absolute zero, a temperature is adopted at which it is assumed that there is no heat; and tables of data are constructed on that basis for practical use. Data tables giving the heat content of the most commonly used refrigerants start at 40°F below zero as the assumed point of no heat; tables for water and steam start at 32°F above zero. Tables of data usually contain a notation showing the starting point for heat content measurement.

DAY-TON OF REFRIGERATION

A day-ton of refrigeration (sometimes incorrectly called a ton of refrigeration) is the amount of refrigeration produced by melting 1 ton of ice at a temperature of 32°F in 24 hours. A day-ton is often used to express the amount of cooling produced by a refrigerator or air-conditioner. For example, a 1-ton air-conditioner can remove as much heat in 24 hours as 1 ton of 32°F ice that melts and becomes water at 32°F.

It is a rate of removing heat, rather than a quantity of heat. A rate can be converted to Btu per day, hour, or minute. To find the rate, proceed as follows:

- Per Day: Multiply 2,000 (number of pounds of ice in 1 ton) by 144 (latent heat of fusion per pound) = 288,000 Btu per day
- Per Hour: 288,000 (Btu per day) ÷ 24 (hours in a day) = 12,000

So, a "1-ton" air-conditioner would have a rating of 12,000 Btu per hour.

PRESSURE

PRESSURE is defined as a force per unit area. It is usually measured in pounds per square inch (psi). Pressure may be in one direction, several directions, or in all directions, as shown in figure 6-3. The ice (solid) exerts pressure downward. The water (fluid) exerts pressure on all wetted surfaces of the container. Gases exert pressure on all inside surfaces of their containers.

Pressure is usually measured on gauges that have one of two different scales. One scale is read as so many pounds per square inch gauge (psig) and indicates the pressure above atmospheric pressure surrounding the gauge. The other type of scale is read as so many pounds per square inch absolute (psia) and indicates the pressure above absolute zero pressure (a perfect vacuum).

Atmospheric Pressure

Atmospheric pressure is the pressure of the weight of air above a point on, above, or under the earth. At sea level, ATMOSPHERIC PRESSURE is 14.7 psia, as shown in figure 6-4. As one ascends, the atmospheric pressure decreases about 1.0 psi for every 2,343 feet. Below sea level in excavations and depressions, atmospheric pressure increases. Pressures underwater differ from those under air only because the weight of the water must be added to the pressure of the air.

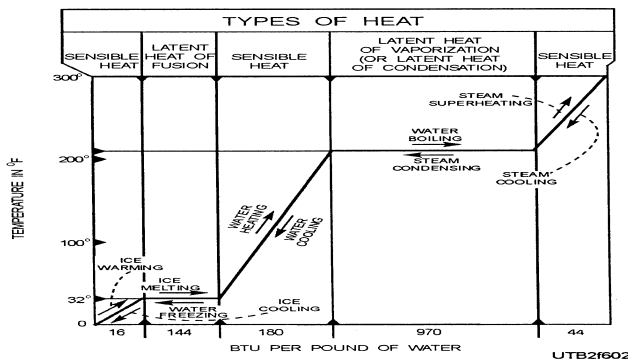


Figure 6-2.—Relationship between temperature and the amount of heat required per pound (for water at atmospheric pressure).

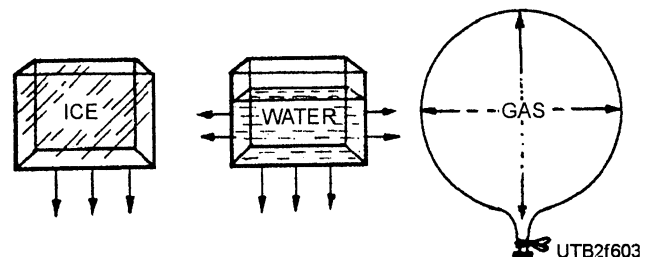


Figure 6-3.—Exertion of pressures.

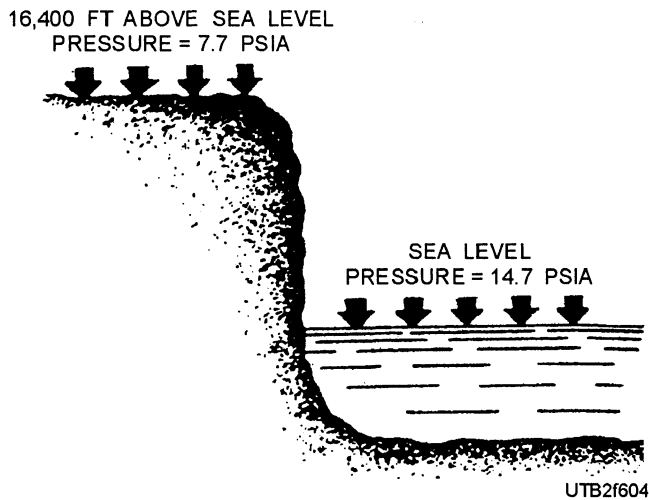


Figure 6-4.—Atmospheric pressure.

Scale Relationships

A relationship exists between the readings of a gauge calibrated in psig and calibrated in psia. As shown in figure 6-5, when the psig gauge reads 0, the

ABSOLUTE SCALE (PSIA)	GAUGE SCALE (PSIG)	INCHES OF MERCURY	INCHES OF WATER
44.7	30	NOT USED	NOT USED
24.7	10	NOT USED	NOT USED
14.7	0	0	0
0	NOT USED	-30	-408

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Figure 6-5.—Pressure relationship.

psia gauge reads the atmospheric pressure (14.7 psia at sea level). In other words, the psia reading equals the psig reading plus the atmospheric pressure (7.7 psia at 16,400 feet), or, a psig reading equals the psia reading minus the atmospheric pressure.

For pressure less than the atmospheric pressure (partial vacuums), a measuring device with a scale reading in inches of mercury (Hg) or in inches of water (H₂O) is used. A perfect vacuum is equal to -30 inches of mercury or -408 inches of water (fig. 6-5). In refrigeration work, pressures above atmospheric are measured in pounds per square inch, and pressures below atmospheric are measured in inches of mercury.

Effects of Pressure on Gases

The exertion of pressure on a substance with a constant temperature decreases its volume in proportion to the increase of pressure. For example, suppose that a given amount of gas is placed in a cylinder that is sealed on one end and has a movable piston on the other end. When 60 psi of absolute pressure is exerted on the piston, as shown in view A of figure 6-6, the volume of the gas is compressed to 3 cubic feet. When 90 psi of absolute pressure is exerted on the piston, as shown in view B, the volume of the gas is compressed to 1.5 cubic feet. Finally, when 180 psi of absolute pressure is exerted on the piston, as shown in view C, the volume of the gas is compressed to 1 cubic foot. Thus, if a given amount of gas is confined in a container and subject to changes of pressure, its volume changes, so the product of volume multiplied by absolute pressure is always the same.

Pressure has a relationship to the boiling point of a substance. There is a definite temperature at which a liquid boils for every definite pressure exerted upon it.

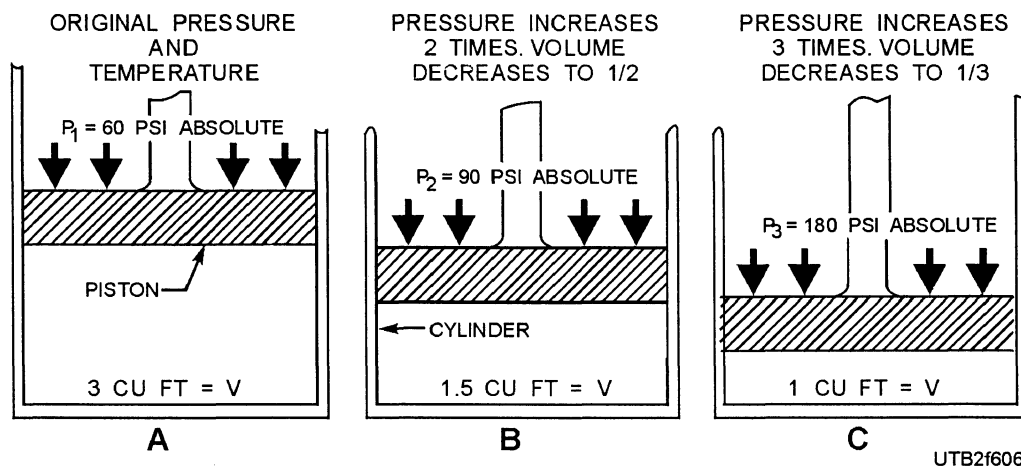


Figure 6-6.—Pressure-volume relationship.

For instance, water boils at 212°F at atmospheric pressure (14.7 psia), as shown in view A, figure 6-7. The same water boils at 228°F if the pressure is raised 5.3 psig (20 psia), as shown in view B, figure 6-7. On the other hand, the same water boils at 32°F in a partial vacuum of 29.74 inches of mercury (Hg), as shown in figure 6-8.

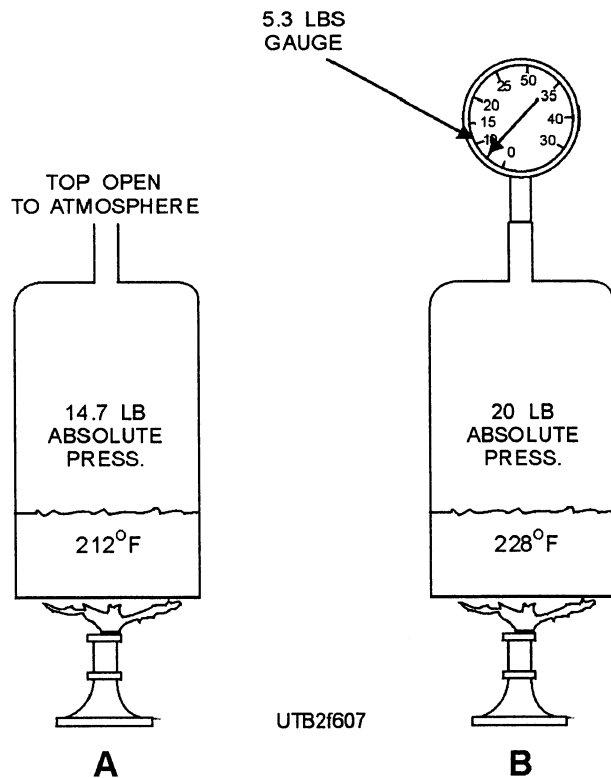


Figure 6-7.—A. Water boils at atmospheric pressure; B. Water boils at 20-psia absolute pressure.

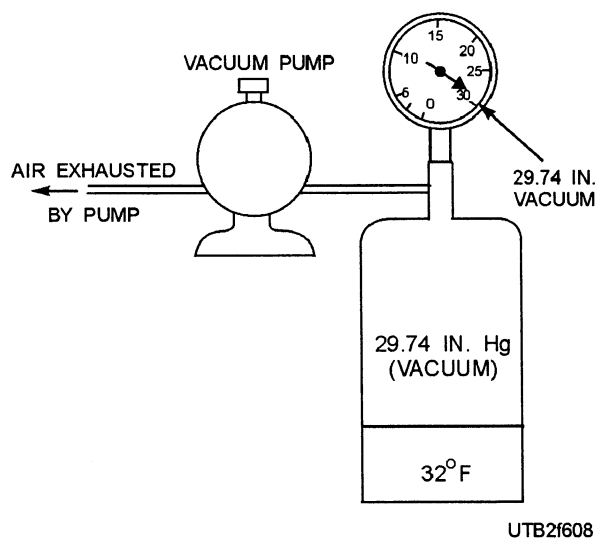


Figure 6-8.—Water boils quicker in a vacuum.

This effect of reduced pressure on the boiling temperature of refrigerants makes the operation of a refrigeration system possible. The pressure temperature relationship chart in figure 6-9 gives the pressures for several different refrigerants.

An increase in the temperature of a refrigerant results in an increase in pressure, and a decrease in temperature causes a decrease in pressure. By the same token, a decrease in pressure results in a corresponding decrease in temperature.

This means that as the pressure of a refrigerant is increased, so is the temperature at which the refrigerant boils. Thus, by regulating the pressure of the refrigerant, the temperature at which evaporation takes place and at which the latent heat of evaporation is used can be controlled.

VAPORIZATION

VAPORIZATION is the process of changing a liquid to vapor, either by evaporation or boiling. When a glass is filled with water, as shown in figure 6-10, and exposed to the rays of the sun for a day or two, you should note that the water level drops gradually. The loss of water is due to evaporation. Evaporation, in this case, takes place only at the surface of the liquid. It is gradual, but the evaporation of the water can be speeded up if additional heat is applied to it. In this case, the boiling of the water takes place throughout the interior of the liquid. Thus the absorption of heat by a liquid causes it to boil and evaporate.

Vaporization can also be increased by reducing the pressure on the liquid, as shown in figure 6-11. Pressure reduction lowers the temperature at which liquid boils and hastens its evaporation. When a liquid evaporates, it absorbs heat from warmer surrounding objects and cools them. Refrigeration by evaporation is based on this method. The liquid is allowed to expand under reduced pressure, vaporizing and extracting heat from the container (freezing compartment), as it changes from a liquid to a gas. After the gas is expanded (and heated), it is compressed, cooled, and condensed into a liquid again.

CONDENSATION

CONDENSATION is the process of changing a vapor into a liquid. For example, in figure 6-12, a warm atmosphere gives up heat to a cold glass of water, causing moisture to condense out of the air and form on the outside surface of the glass. Thus the removal of heat from a vapor causes the vapor to condense.

PRESSURE TEMPERATURE CHART												
Temp °F	113	141b	123	11	114	124	134a	12	500	22	502	125
-40.0	29.5	29.0	28.8	28.4	26.1	22.8*	14.7	11.0	7.6	0.6	4.1	4.9
-35.0	29.4	28.8	28.6	28.1	25.4		12.3	8.4	4.6	2.6	6.5	
-30.0	29.3	28.6	28.3	27.8	24.7	20.2*	9.7	5.5	1.2	4.9	9.2	10.6
-25.0	29.2	28.3	28.1	27.4	23.8		6.8	2.3	1.2	7.5	12.1	
-20.0	29.0	28.1	27.7	27.0	22.9	16.9*	3.6	0.6	3.2	10.2	15.3	17.4
-15.0	28.8	27.7	27.3	26.6	21.8		0.0	2.5	5.4	13.2	18.8	
-10.0	28.7	27.3	26.9	26.0	20.6	12.7*	2.0	4.5	7.8	16.5	22.6	25.6
-5.0	28.4	26.9	26.4	25.4	19.3		4.1	6.7	10.4	20.1	26.7	
0.0	28.2	26.4	25.8	24.7	17.8	7.6*	6.5	9.2	13.3	24.0	31.1	35.1
5.0	27.9	25.8	25.2	23.9	16.2		9.1	11.8	16.4	28.3	35.9	
10.0	27.5	25.2	24.5	23.1	14.4	1.4*	12.0	14.7	19.7	32.8	41.0	46.3
15.0	27.2	24.5	23.7	22.1	12.4		15.1	17.7	23.3	37.8	46.5	
20.0	26.7	23.7	22.8	21.1	10.2	3.0	18.4	21.1	27.2	43.1	52.5	59.2
25.0	26.3	22.8	21.8	19.9	7.8		22.1	24.6	31.4	48.8	58.8	
30.0	25.7	21.8	20.7	18.6	5.1	7.5	26.1	28.5	36.0	54.9	65.6	74.1
35.0	25.1	20.7	19.5	17.1	2.2		30.4	32.6	40.8	61.5	72.8	
40.0	24.4	19.5	18.1	15.6	0.4	12.7	35.0	37.0	46.0	68.5	80.5	91.2
45.0	23.7	18.1	16.6	13.8	2.1		40.0	41.7	51.6	76.1	88.7	
50.0	22.9	16.7	15.0	12.0	3.9	18.8	45.4	46.7	57.5	84.1	97.4	110.6
55.0	21.9	13.1	13.1	9.9	5.9		51.2	52.1	63.8	92.6	106.6	
60.0	20.9	13.4	11.2	7.7	8.0	25.9	57.4	57.8	70.6	101.6	116.4	132.8
65.0	19.8	11.5	9.0	5.2	10.3		64.0	63.8	77.7	111.3	127.6	
70.0	18.6	9.4	6.6	2.6	12.7	34.1	71.1	70.2	85.3	121.4	137.6	157.8
75.0	17.3	7.2	4.1	0.1	15.3		78.6	77.0	93.4	132.2	149.1	
80.0	15.8	4.8	1.3	1.6	18.2	43.5	86.7	84.2	101.9	143.7	161.2	186.0
85.0	14.2	2.3	0.9	3.3	21.2		95.2	91.7	110.9	155.7	174.0	
90.0	12.5	0.2	2.5	5.0	24.4	54.1	104.3	99.7	120.5	168.4	187.4	217.5
95.0	10.6	1.7	4.2	6.9	27.8		113.9	108.2	130.5	181.8	201.4	
100.0	8.6	3.2	6.1	8.9	31.4	66.2	124.1	117.0	141.1	196.0	216.2	252.7
105.0	6.4	4.8	8.1	11.1	35.3		134.9	126.4	152.2	210.8	231.7	
110.0	4.0	6.6	10.2	13.4	39.4	79.7	146.3	136.2	163.9	226.4	247.9	291.6
115.0	1.4	8.4	12.6	15.9	43.8		158.4	146.5	176.3	242.8	264.9	
120.0	0.7	10.4	15.0	18.5	48.4	94.9	171.1	157.3	189.2	260.0	282.7	334.3

Vapor pressures in psig, except (*) which are inches of mercury (Hg).

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Figure 6-9.—Pressure temperature chart.

An increase in pressure on a confined vapor also causes the vapor to change to a liquid. This fact is shown in figure 6-13. When the compressor increases the pressure on the vapor, the condensing vapor changes to a liquid and gives up heat to the cooler surrounding objects and atmosphere.

These conditions exist when the vaporized refrigerant is compressed by the compressor of a refrigeration system and forced into the condenser.

The condenser removes the superheat, latent heat of vaporization, and, in some cases, sensible heat from the refrigerant.

- Q1. When two substances of different temperatures are brought in contact with each other, heat will flow from the colder substance to the warmer substance. True/False.*
- Q2. What is specific heat?*

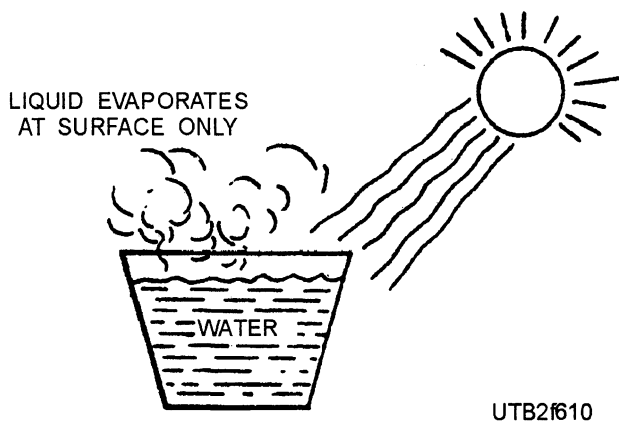


Figure 6-10.—Normal surface evaporation.

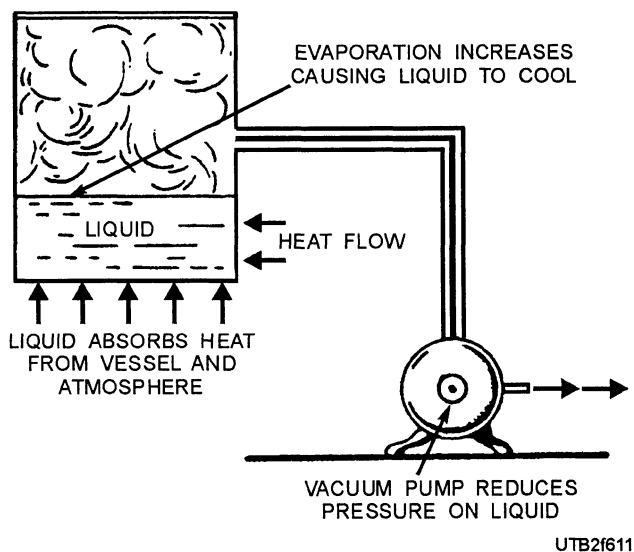


Figure 6-11.—Evaporation by pressure reduction.

- Q3. What is the difference between "sensible heat" and "latent heat"?
- Q4. What is the atmospheric pressure at 4,686 feet?
- Q5. Exertion of pressure on a substance with a constant pressure does what to the substance?
- Q4. Removal of heat from a vapor causes what change to occur?

MECHANICAL REFRIGERATION SYSTEMS

Learning Objective: Identify and understand different types of refrigeration system components and their operation.

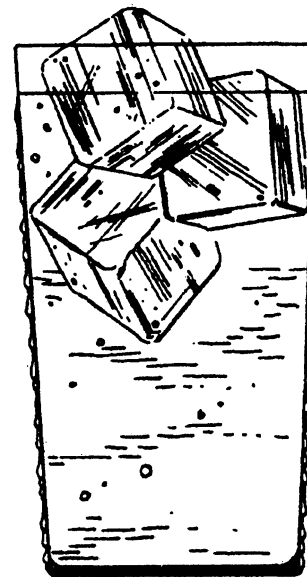


Figure 6-12.—Condensation of moisture on a glass of cold water.

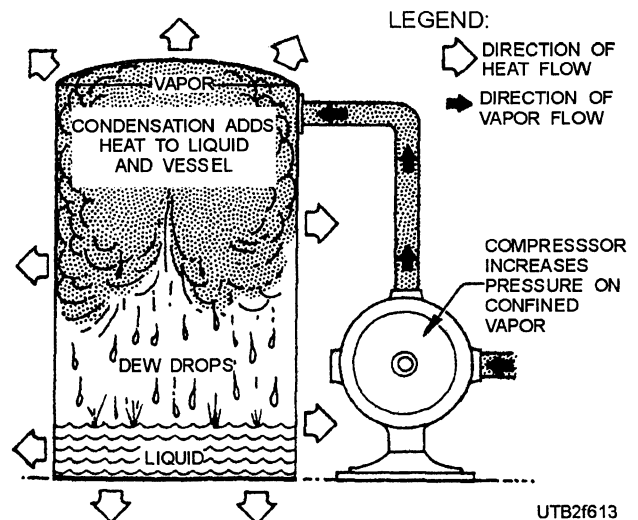


Figure 6-13.—Pressure causes a vapor to condense.

Mechanical refrigeration systems are an arrangement of components in a system that puts the theory of gases into practice to provide artificial cooling. To do this, you must provide the following: (1) a metered supply of relatively cool liquid under pressure; (2) a device in the space to be cooled that operates at reduced pressure so that when the cool, pressurized liquid enters, it will expand, evaporate, and take heat from the space to be cooled; (3) a means of repressurizing (compressing) the vapor; and (4) a means of condensing it back into a liquid, removing its

superheat, latent heat of vaporization, and some of its sensible heat.

Every mechanical refrigeration system operates at two different pressure levels. The dividing line is shown in figure 6-14. The line passes through the discharge valves of the compressor on one end and through the orifice of the metering device or expansion valve on the other.

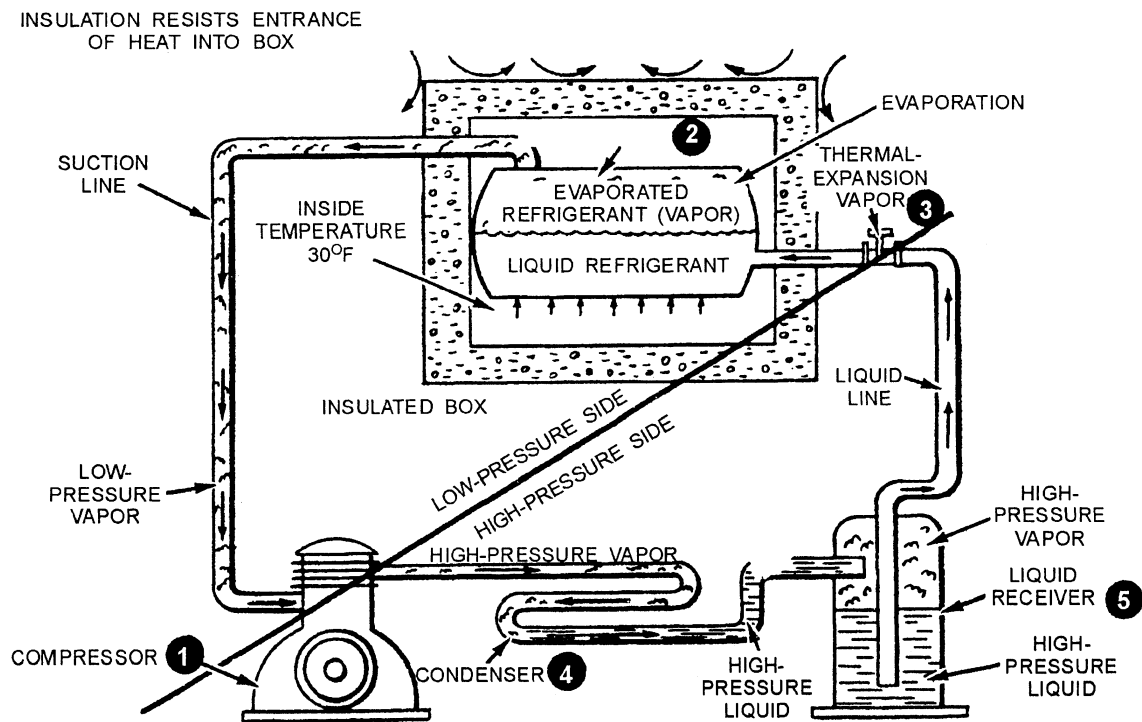
The high-pressure side of the refrigeration system comprises all the components that operate at or above condensing pressure. These components are the discharge side of the compressor, the condenser, the receiver, and all interconnected tubing up to the metering device or expansion valve.

The low-pressure side of a refrigeration system consists of all the components that operate at or below evaporating pressure. These components comprise the low-pressure side of the expansion valve, the evaporator, and all the interconnecting tubing up to and including the low side of the compressor.

Refrigeration mechanics call the pressure on the high side discharge pressure, head pressure, or high-side pressure. On the low side, the pressure is called suction pressure or low-side pressure.

The refrigeration cycle of a mechanical refrigeration system may be explained by using figure 6-14. The pumping action of the compressor (1) draws vapor drawn from the evaporator (2). This action reduces the pressure in the evaporator, causing the liquid particles to evaporate. As the liquid particles evaporate, the evaporator is cooled. Both the liquid and vapor refrigerant tend to extract heat from the warmer objects in the insulated refrigerator cabinet. The ability of the liquid to absorb heat as it vaporizes is very high in comparison to that of the vapor. As the liquid refrigerant is vaporized, the low-pressure vapor is drawn into the suction line by the suction action of the compressor (1). The evaporation of the liquid refrigerant would soon remove the entire refrigerant from the evaporator if it were not replaced. The replacement of the liquid refrigerant is usually controlled by a metering device or expansion valve (3). This device acts as a restrictor to the flow of the liquid refrigerant in the liquid line. Its function is to change the high-pressure, subcooled liquid refrigerant to low-pressure, low-temperature liquid particles, which will continue the cycle by absorbing heat.

The refrigerant low-pressure vapor drawn from the evaporator by the compressor through the suction line, in turn, is compressed by the compressor to a high-pressure vapor, which is forced into the



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Figure 6-14.—Refrigeration cycle.

condenser (4). In the condenser, the high-pressure vapor condenses to a liquid under high pressure and gives up heat to the condenser. The heat is removed from the condenser by the cooling medium of air or water. The condensed liquid refrigerant is then forced into the liquid receiver (5) and through the liquid line to the expansion valve by pressure created by the compressor, making a complete cycle.

Although the receiver is indicated as part of the refrigeration system in figure 6-14, it is not a vital component. However, the omission of the receiver requires exactly the proper amount of refrigerant in the system. The refrigerant charge in systems without receivers is to be considered critical, as any variations in quantity affects the operating efficiency of the unit.

The refrigeration cycle of any refrigeration system must be clearly understood by a mechanic before repairing the system. Knowing how a refrigerant works makes it easier to detect faults in a refrigeration system.

COMPONENTS

The refrigeration system consists of four basic components—the compressor, the condenser, the liquid receiver, the evaporator, and the control devices. These components are essential for any system to operate on the principles previously discussed. Information on these components is described in the following sections.

Compressors

Refrigeration compressors have but one purpose—to withdraw the heat-laden refrigerant vapor from the evaporator and compress the gas to a pressure that will liquefy in the condenser. The designs of compressors vary, depending upon the application and type of refrigerant. There are three types of compressors classified according to the principle of operation—reciprocating, rotary, and centrifugal.

You may recall that material on compressors was presented in chapter 6, *Utilitiesman Basic*, volume 1. They will not be explained further here except to discuss the special methods used to seal compressors to prevent escape of refrigerant. Many refrigerator compressors have components besides those normally found on compressors, such as unloaders, oil pumps, mufflers, and so on. These devices are too complicated to explain here. Before repairing any compressor, check the manufacturer's manual for an explanation of their operation, adjustment, and repair.

EXTERNAL DRIVE COMPRESSOR.—An external drive or open-type compressor is bolted together. Its crankshaft extends through the crankcase and is driven by a flywheel (pulley) and belt, or it can be driven directly by an electric motor. A leakproof seal must be maintained where the crankshaft extends out of the crankcase of an open-type compressor. The seal must be designed to hold the pressure developed inside of the compressor. It must prevent refrigerant and oil from leaking out and prevent air and moisture from entering the compressor. Two types of seals are used—the stationary bellows seal and the rotating bellows seal.

An internal stationary crankshaft seal shown in figure 6-15 consists of a corrugated thin brass tube (seal bellows) fastened to a bronze ring (seal guide) at one end and to the flange plate at the other. The flange plate is bolted to the crankcase with a gasket between the two units. A spring presses the seal guide mounted on the other end of the bellows against a seal ring positioned against the shoulder of the crankshaft. As the pressure builds up in the crankcase, the bellows tend to lengthen, causing additional force to press the seal guide against the seal ring. Oil from the crankcase lubricates the surfaces of the seal guide and seal ring. This forms a gastight sea whether the compressor is operating or idle.

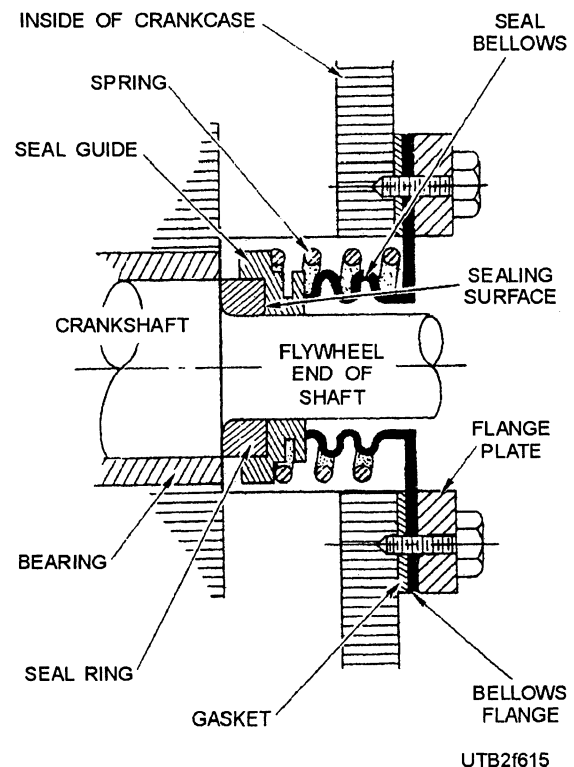


Figure 6-15.—An internal stationary bellows crankshaft seal.

An external stationary bellows crankshaft seal is shown in figure 6-16. This seal is the same as the internal seal, except it is positioned on the outside of the crankcase.

An external rotating bellows crankcase seal is shown in figure 6-17. This seal turns with the crankshaft. This seal also consists of a corrugated thin brass tube (seal bellows) with a seal ring fastened to one end and a seal flange fastened to the other. A seal spring is enclosed within the bellows. The complete bellows assembly slips on the end of the crankshaft and is held in place by a nut. The seal ring that is the inner portion of the bellows is positioned against a nonrotating seal fastened directly to the crankcase. During operation, the complete bellows assembly rotates with the shaft, causing the seal ring to rotate against the stationary seal. The pressure of the seal spring holds the seal ring against the seal. The expansion of the bellows caused by the pressure from the crankcase also exerts pressure on the seal ring. Because of this design, double pressure is exerted against the seal ring to provide a gastight seal.

HERMETIC COMPRESSOR.—In the hermetically sealed compressor, the electric motor and compressor are both in the same airtight (hermetic) housing and share the same shaft. Figure 6-18 shows a hermetically sealed unit. Note that after assembly, the two halves of the case are welded together to form an airtight cover. Figure 6-19 shows an accessible type of hermetically sealed unit. The compressor, in this case, is a double-piston reciprocating type. Other compressors may be of the centrifugal or rotary types.

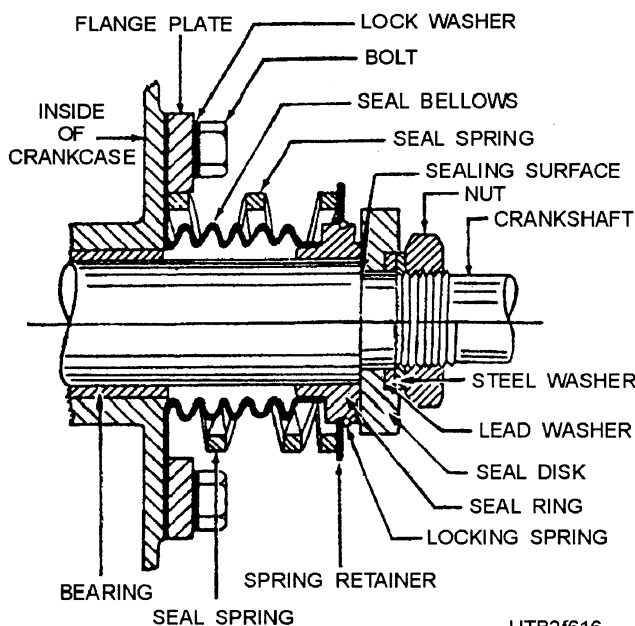
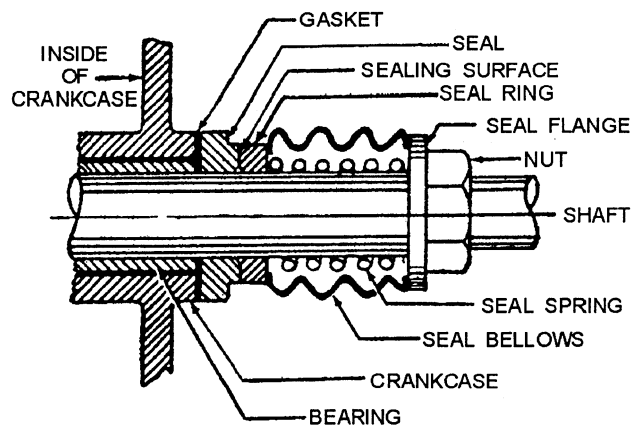


Figure 6-16.—An external stationary bellows crankshaft seal.



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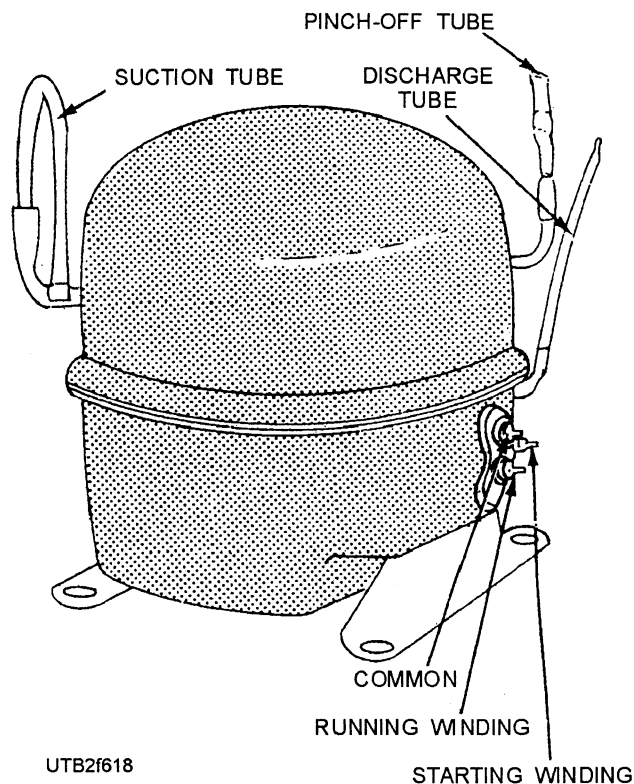
Figure 6-17.—An external rotating bellows crankcase seal.

Cooling and lubrication are provided by the circulating oil and the movement of the refrigerant vapor throughout the case.

The advantages of the hermetically sealed unit (elimination of pulleys, belts and other coupling methods, elimination of a source of refrigerant leaks) are offset somewhat by the inaccessibility for repair and generally lower capacity.

Condensers

The condenser removes and dissipates heat from the compressed vapor to the surrounding air or water to



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Figure 6-18.—Hermetic compressor.

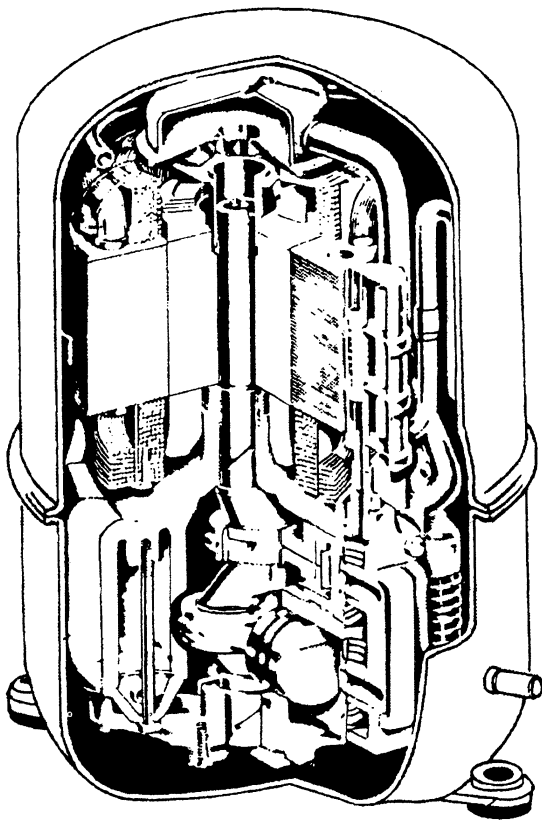


Figure 6-19.—A cutaway view of a hermetic compressor and motor.

condense the refrigerant vapor to a liquid. The liquid refrigerant then falls by gravity to a receiver (usually located below the condenser), where it is stored, and available for future use in the system.

There are three basic types of condensers—air-cooled, water-cooled, and evaporative. The first two are the most common, but the evaporative types are used where low-quality water and its disposal make the use of circulating water-cooled types impractical.

AIR-COOLED CONDENSERS.—The construction of air-cooled condensers makes use of several layers of small tubing formed into flat cells. The external surface of this tubing is provided with fins to ease the transfer of heat from the condensing refrigerant inside the tubes to the air circulated through the condenser core around the external surface of the tubes (fig. 6-20). Condensation takes place as the refrigerant flows through the tubing, and the liquid refrigerant is discharged from the lower ends of the tubing coils to a liquid receiver on the condensing unit assembly.

WATER-COOLED CONDENSERS.—Water-cooled condensers are of the multipass shell and tube type, with circulating water flowing through the tubes. The refrigerant vapor is admitted to the shell

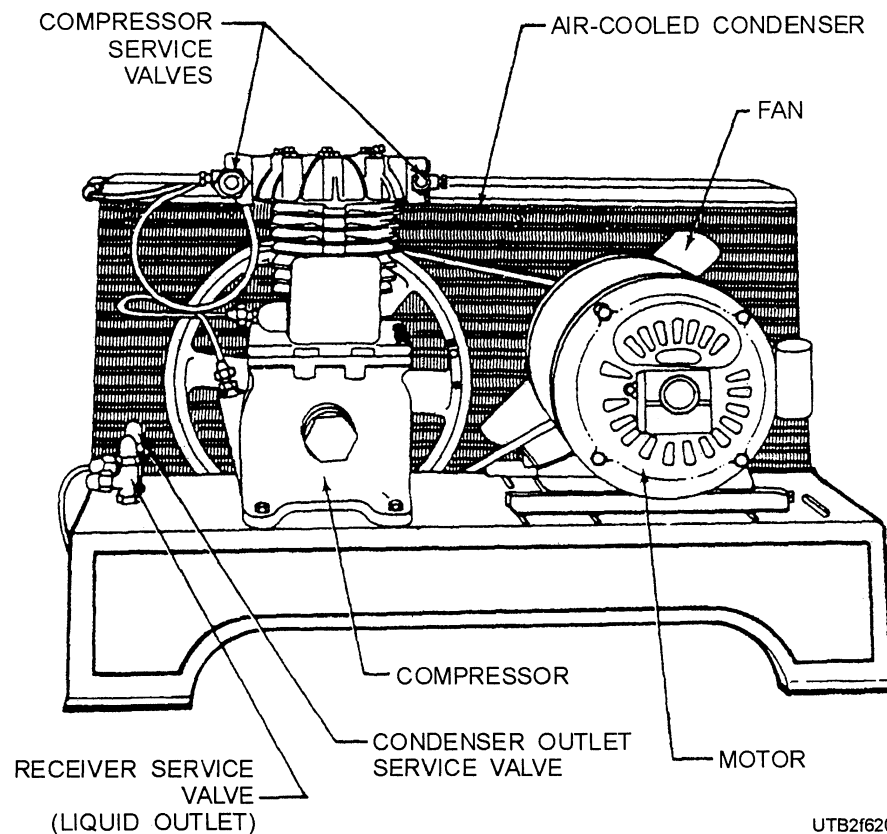


Figure 6-20.—Air-cooled condenser mounted on a compressor unit.

and condensed on the outer surfaces of the tubes (fig. 6-21).

The condenser is constructed with a tube sheet brazed to each end of a shell. Copper-nickel tubes are inserted through drilled openings in the tube sheet and are expanded or rolled into the tube sheet to make a gastight seal. Headers, or water boxes, are bolted to the tube sheet to complete the waterside of the condenser. Zinc-wasting bars are installed in the water boxes to minimize electrolytic corrosion of the condenser parts.

A purge connection with a valve is at the topside of the condenser shell to allow manual release of any accumulated air in the refrigerant circuit.

The capacity of the water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and the temperature of the refrigerant gas. The capacity of the condenser varies whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water increases the capacity of the condenser. The use of colder water can cause the temperature difference to increase.

EVAPORATIVE CONDENSERS.—An evaporative condenser operates on the principle that heat can be removed from condensing coils by spraying them with water or letting water drip onto them and then forcing air through the coils by a fan.

This evaporation of the water cools the 'coils and condenses the refrigerant within.

Liquid Receiver

A liquid receiver as shown at position (5) on figure 6-14, serves to accumulate the reserve liquid refrigerant, to provide a storage for off-peak operation, and to permit pumping down of the system. The receiver also serves as a seal against the entrance of gaseous refrigerant into the liquid line. When stop valves are provided at each side of the receiver for confinement of the liquid refrigerant, a pressure relief valve is generally installed between the valves in the receiver and condenser equalizing line to protect the receiver against any excessive hydraulic pressure being built up.

Evaporators

The evaporator is a bank or coil of tubing placed inside the refrigeration space. The refrigerant is at a low-pressure and low-temperature liquid, as it enters the evaporator.

As the refrigerant circulates through the evaporator tubes, it absorbs its heat of vaporization from the surrounding space and substances. The absorption of this heat causes the refrigerant to boil. As the temperature of the surrounding space (and

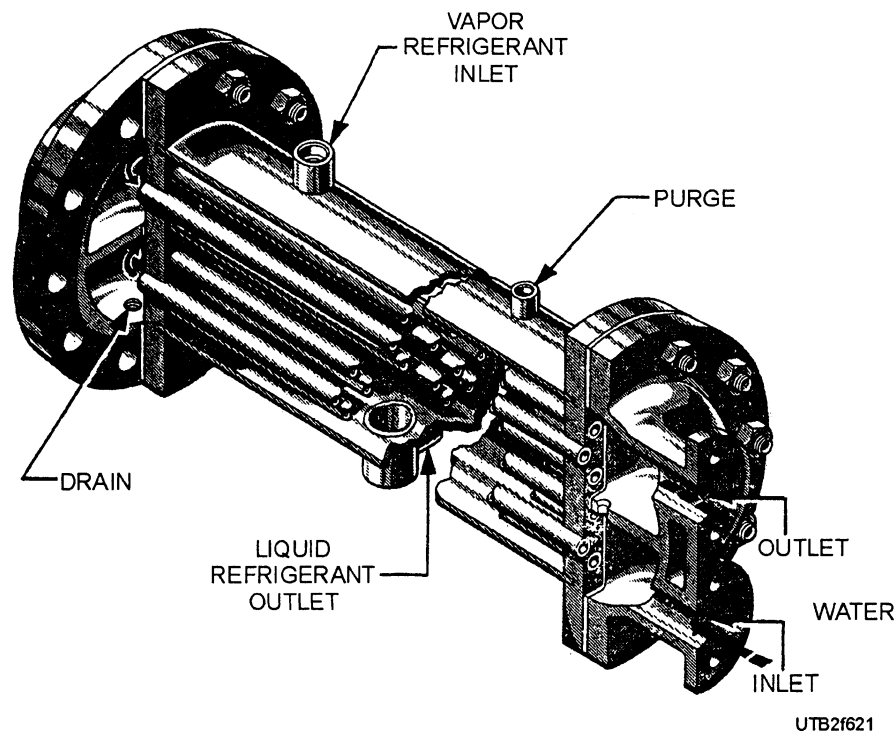


Figure 6-21.—Water-cooled condenser.

contents) is lowered, the liquid refrigerant gradually changes to a vapor. The refrigerant vapor then passes into the suction line by the action of the compressor.

Most evaporators are made of steel, copper, brass, stainless steel, aluminum, or almost any other kind of rolled metal that resists the corrosion of refrigerants and the chemical action of the foods.

Evaporators are mainly of two types—dry or flooded. The inside of a dry evaporator refrigerant is fed to the coils only as fast as necessary to maintain the temperature wanted. The coil is always filled with a mixture of liquid and vapor refrigerant. At the inlet side of the coil, there is mostly liquid; the refrigerant flows through the coil (as required); it is vaporized until, at the end, there is nothing but vapor. In a flooded evaporator, the evaporator is always filled with liquid refrigerant. A float maintains liquid refrigerant at a constant level. As fast as the liquid refrigerant evaporates, the float admits more liquid, and, as a result, the entire inside of the evaporator is flooded with liquid refrigerant up to a certain level determined by the float.

The two basic types of evaporators are further classified by their method of evaporation, either direct expanding or indirect expanding. In the direct-expanding evaporator, heat is transferred directly from the refrigerating space through the tubes and absorbed by the refrigerant. In the indirect-expanding evaporator, the refrigerant in the evaporator is used to cool some secondary medium, other than air. This secondary medium or refrigerant maintains the desired temperature of the space. Usually brine, a solution of calcium chloride is used as the secondary refrigerant.

Natural convection or forced-air circulation is used to circulate air within a refrigerated space. Air around the evaporator must be moved to the stored food so that heat can be extracted, and the warmer air from the food returned to the evaporator. Natural convection can be used by installing the evaporator in the uppermost portion of the space to be refrigerated, so heavier cooled air will fall to the lower food storage and the lighter food-warmed air will rise to the evaporator. Forced-air circulation speeds up this process and is usually used in large refrigerated spaces to ensure all areas are cooled.

Control Devices

To maintain correct operating conditions, control devices are needed in a refrigeration system. Some of the control devices are discussed in this chapter.

METERING DEVICES.—Metering devices, such as expansion valves and float valves, control the flow of liquid refrigerant between the high side and the low side of the system. It is at the end of the line between the condenser and the evaporator. These devices are of five different types: an automatic expansion valve (also known as a constant-pressure expansion valve), a thermostatic expansion valve, low-side and high-side float valves, and a capillary tube.

Automatic Expansion Valve.—An automatic expansion valve (fig. 6-22) maintains a constant pressure in the evaporator. Normally this valve is used only with direct expansion, dry type of evaporators. In operation, the valve feeds enough liquid refrigerant to the evaporator to maintain a constant pressure in the coils. This type of valve is generally used in a system where constant loads are expected. When a large variable load occurs, the valve will not feed enough refrigerant to the evaporator under high load and will overfeed the evaporator at low load. Compressor damage can result when slugs of liquid enter the compressor.

Thermostatic Expansion Valve.—Before discussing the thermostatic expansion valve, let's explain the term SUPERHEAT. A vapor gas is superheated when its temperature is higher than the boiling point corresponding to its pressure. When the boiling point begins, both the liquid and the vapor are at the same temperature. But in an evaporator, as the gas vapor moves along the coils toward the suction line, the gas may absorb additional heat and its temperature rises. The difference in degrees between the saturation temperature and the increased temperature of the gas is called superheat.

A thermostatic expansion valve (fig. 6-22) keeps a constant superheat in the refrigerant vapor leaving the coil. The valve controls the liquid refrigerant, so the evaporator coils maintain the correct amount of refrigerant at all times. The valve has a power element that is activated by a remote bulb located at the end of the evaporator coils. The bulb senses the superheat at the suction line and adjusts the flow of refrigerant into the evaporator. As the superheat increases (suction line), the temperature, and therefore the pressure, in the remote bulb also increases. This increased pressure, applied to the top of the diaphragm, forces it down along with the pin, which, in turn, opens the valve, admitting replacement refrigerant from the receiver to flow into the evaporator. This replacement has three effects. First, it provides additional liquid

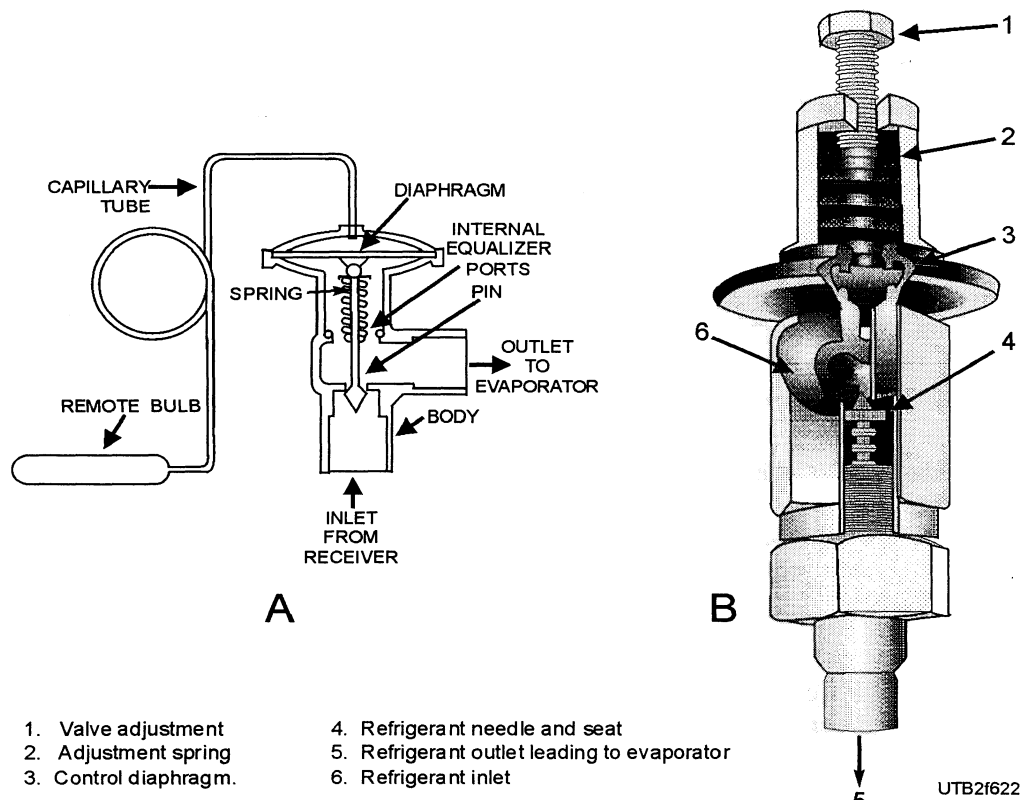


Figure 6-22—A. Thermostatic expansion valve; B. Automatic expansion valve.

refrigerant to absorb heat from the evaporator. Second, it applies higher pressure to the bottom of the diaphragm, forcing it upward, tending to close the valve. And third, it reduces the degree of superheat by forcing more refrigerant through the suction line.

Low-Side Float Expansion Valve.—The low-side float expansion valve (fig. 6-23) controls the liquid refrigerant flow where a flooded evaporator is used. It consists of a ball float in either a chamber or the evaporator on the low-pressure side of the system.

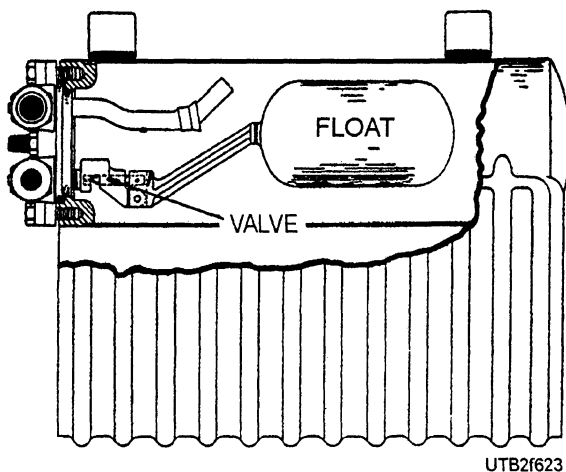


Figure 6-23.—A low-side float expansion valve.

The float actuates a needle valve through a lever mechanism. As the float lowers, refrigerant enters through the open valve; when it rises, the valve closes.

High-Side Float Expansion Valve.—In a high-side float expansion valve (fig. 6-24), the valve float is in a liquid receiver or in an auxiliary container on the high-pressure side of the system. Refrigerant from the condenser flows into the valve and immediately opens it, allowing refrigerant to expand and pass into the evaporator. Refrigerant charge is critical. An overcharge of the system floods back and damages the compressor. An undercharge results in a capacity drop.

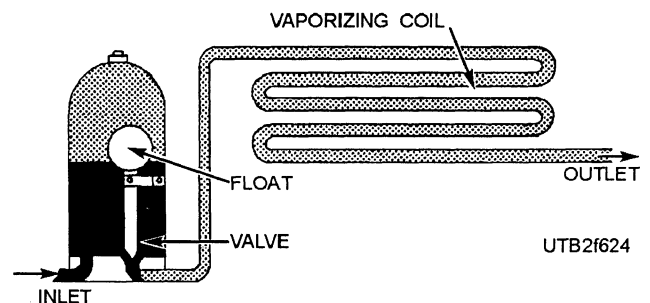


Figure 6-24.—A high-side float expansion valve.

Capillary Tube.—The capillary tube consists of a long tube of small diameter. It acts as a constant throttle on the refrigerant. The length and diameter of the tube are important; any restrictions cause trouble in the system. It feeds refrigerant to the evaporator as fast as it is produced by the condenser. When the quantity of refrigerant in the system is correct or the charge is balanced, the flow of refrigerant from the condenser to the evaporator stops when the compressor unit stops. When the condensing unit is running, the operating characteristics of the capillary tube equipped evaporator are the same as if it were equipped with a high-side float.

The capillary tube is best suited for household boxes, such as freezers and window air-conditioners, where the refrigeration load is reasonably constant and small horsepower motors are used.

Accessory Devices

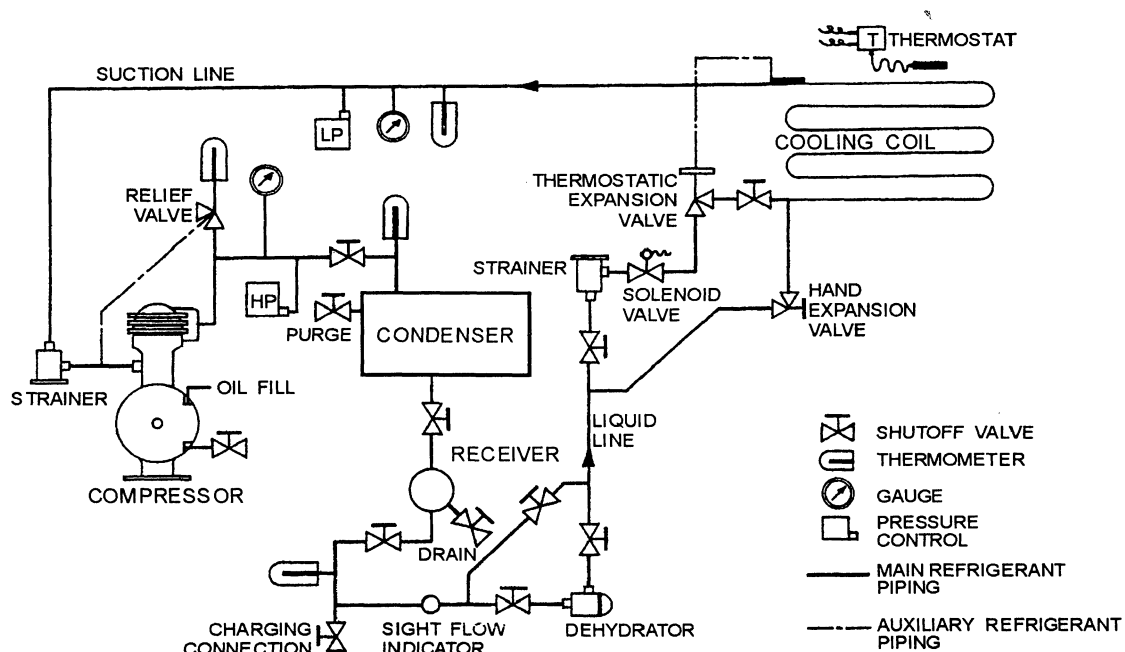
The four basic or major components of a refrigeration system just described are enough for a refrigeration unit to function. However, additional devices, such as the receiver already described, make for a smoother and more controlled cycle. Some of the accessory devices used on a refrigeration unit are described in this section. Before proceeding, take a close look at figure 6-25 that shows one type of refrigeration system with additional devices installed.

Some of the devices and their functions are explained to help you understand installation and troubleshooting of a refrigeration unit.

RELIEF VALVE.—A refrigeration system is a sealed system in which pressures vary. Excessive pressures can cause a component of the system to explode. The National Refrigeration Code makes the installation of a relief valve mandatory. A spring-loaded relief valve is most often used and it is installed in the compressor discharge line between the compressor discharge connection and the discharge line stop valve to protect the high-pressure side of the system. No valves can be installed between the compressor and the relief valve. The discharge from the relief valve is led to the compressor suction line.

DISCHARGE PRESSURE GAUGE AND THERMOMETER. —A discharge pressure gauge and thermometer are installed in the compressor discharge line (liquid line) to show the pressure and temperature of the compressed refrigerant gas. The temperature indicated on the gauge is always higher than that corresponding to the pressure when the compressor is operating.

COMPRESSOR MOTOR CONTROLS.—The starting and stopping of the compressor motor is usually controlled by either a pressure-actuated or temperature-actuated motor control. The operation of the pressure motor control depends on the relationship



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Figure 6-25.—A basic refrigeration system.

between pressure and temperature. A pressure motor control is shown in figure 6-26. The device consists of a low-pressure bellows, or, in some cases, a low-pressure diaphragm, connected by a small diameter tube to the compressor crankcase or to the suction line. The pressure in the suction line or compressor crankcase is transmitted through the tube and actuates the bellows or diaphragm. The bellows move according to the pressure, and its movement causes an electric switch to start (cut in) or stop (cut out) the compressor motor. Adjustments can be made to the start and stop pressures under the manufacturer's instruction. Usually the cutout pressure is adjusted to correspond to a temperature a few degrees below the desired evaporator coil temperature, and the cut-in pressure is adjusted to correspond to the temperature of the coil.

The temperature-actuated motor control is similar to the pressure device. The main difference is that a temperature-sensing bulb and a capillary tube replace the pressure tube. The temperature motor control cuts in or cuts out the compressor according to the temperature in the cooled space.

The refrigeration system may also be equipped with a high-pressure safety cutout switch that shuts off the power to the compressor motor when the high-side pressure exceeds a preset limit.

SOLENOID STOP VALVES.—Solenoid stop valves, or magnetic stop valves, control gas or liquid

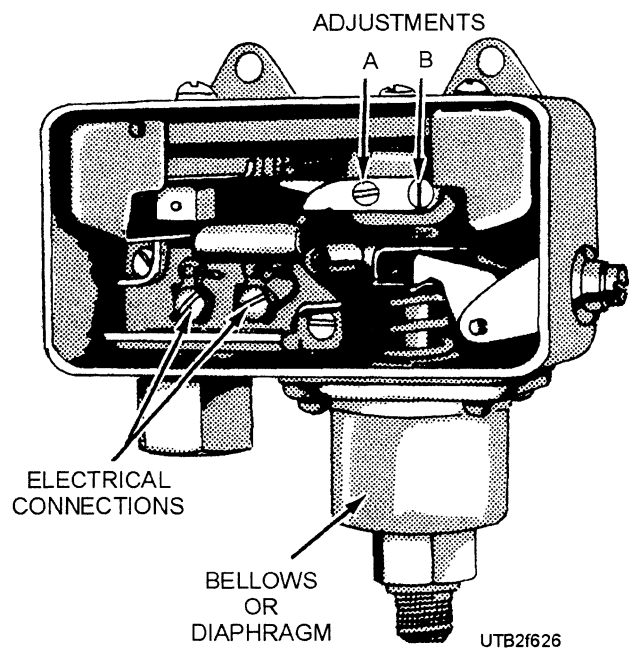


Figure 6-26.—Pressure-actuated motor control.

flow. They are most commonly used to control liquid refrigerant to the expansion valve but are used throughout the system. The compressor motor and solenoid stop valve are electrically in parallel; that is, the electrical power is applied or removed from both at the same time. The liquid line is open for passage of refrigerant only when the compressor is in operation and the solenoid is energized. A typical solenoid stop valve is shown in figure 6-27.

Improper operation of these valves can be caused by a burned-out solenoid coil or foreign material lodged between the stem and the seat of the valve, allowing fluid to leak. Carefully check the valve before replacing or discarding. The valve must be installed so that the coil and plunger are in a true vertical position. When the valve is cocked, the plunger will not reseal properly, causing refrigerant leakage.

THERMOSTAT SWITCH.—Occasionally, a thermostat in the refrigerated space operates a solenoid stop valve, and the compressor motor is controlled independently by a low-pressure switch. The solenoid control switch, or thermostat, makes and breaks the electrical circuit, thereby controlling the liquid refrigerant to the expansion valve. The control bulb is charged with a refrigerant so that temperature changes of the bulb itself produce like changes in pressure within the control bulb. These pressure changes are transmitted through the tubing to the switch power element to operate the switch. The switch opens the contacts and thus releases the solenoid valve, stopping the flow of refrigerant to the cooling coil when the temperature of the refrigerated space has reached the desired point. The compressor continues to operate until it has evacuated the evaporator. The resulting low

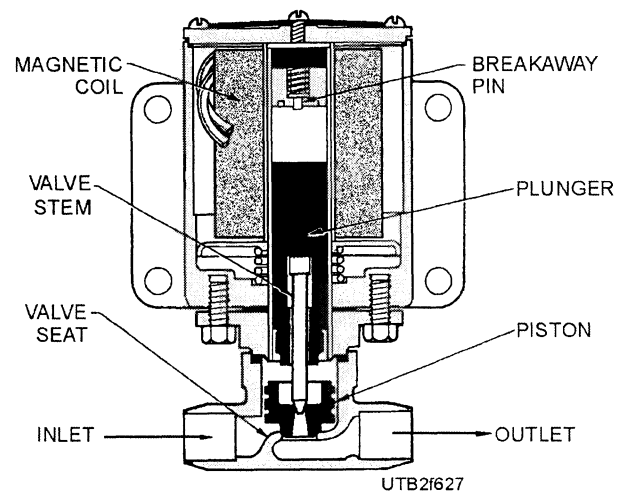


Figure 6-27.—A solenoid stop valve.

pressure in the evaporator then activates the low-pressure switch, which stops the compressor. As the temperature rises, the increase in bulb pressure closes the switch contacts, and the refrigerant is supplied to the expansion valve.

LIQUID LINE.—The refrigerant accumulated in the bottom of the receiver shell is conveyed to the cooling coils through the main refrigerant liquid line. A stop valve and thermometer are usually installed in this line next to the receiver. Where the sight-flow indicator, dehydrator, or filter-drier is close to the receiver, the built-in shutoff valves may be used instead of a separate shutoff valve.

LIQUID LINE FILTER-DRIER OR DEHYDRATOR.—A liquid line filter-drier (fig. 6-28) prevents or removes moisture, dirt, and other foreign materials from the liquid line that would harm the system components and reduce efficiency. This tank like accessory offers some resistance to flow, and, for this reason, some manufacturers install it in a bypass line. A filter-drier consists of a tubular shell with strainers on the inlet and outlet connections to prevent escape of drying material into the system. Some filter-driers are equipped with a sight-glass indicator, as shown in figure 6-28. A dehydrator is similar to a filter-drier, except that it mainly removes moisture.

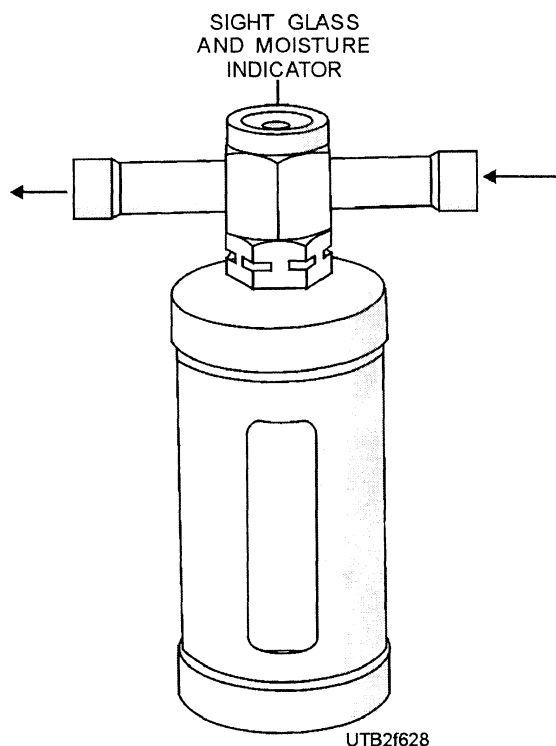


Figure 6-28.—A liquid line filter-drier with sight-glass indicator.

SIGHT-FLOW INDICATOR.—The sight-flow indicator, also known as a sight glass (fig. 6-29), is a special fitting provided with a gasketed glass, single or double port, and furnished with or without seal caps for protection when not in use. The double-port unit permits the use of a flashlight background. The refrigerant may be viewed passing through the pipe to determine the presence and amount of vapor bubbles in the liquid that would indicate low refrigerant or unfavorable operating conditions. Some filter-driers are equipped with built-in sight-flow indicators, as shown in figure 6-29.

SUCTION LINE.—Suction pressure regulators are sometimes placed between the outlet of the evaporator and the compressor to prevent the evaporator pressure from being drawn down below a predetermined level despite load fluctuations. These regulators are usually installed in systems that require a higher evaporator temperature than usual.

PRESSURE CONTROL SWITCHES.—Pressure control switches (fig. 6-30), often called low-pressure cutouts, are essentially a single-pole, single-throw electrical switch and are mainly used to control starting and stopping of the compressor. The suction pressure acts on the bellows of the power element of the switch and produces movement of a lever mechanism operating electrical contacts. A rise in pressure closes the switch contacts and thereby completes the circuit of the motor controller, which, in turn, starts the compressor automatically. As the operation of the compressor gradually decreases the suction pressure, the movement of the switch linkage

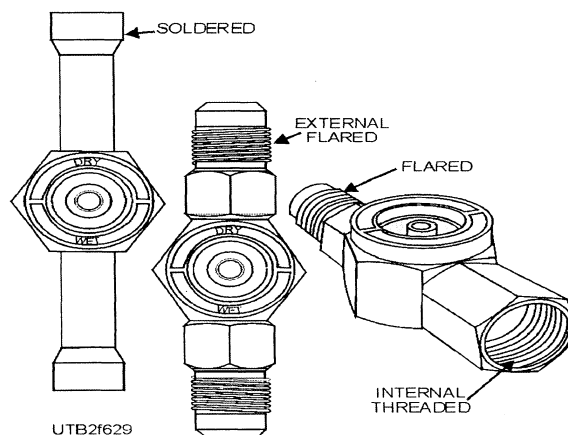


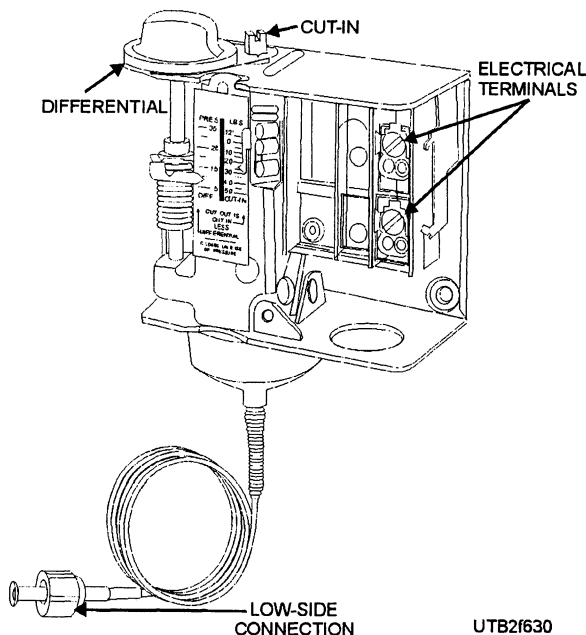
Figure 6-29.—Sight-flow indicators with different types of connections.

reverses until the contacts are separated at a pre-determined low-suction pressure, thus breaking the motor controller circuit and stopping the compressor.

SUCTION LINE FILTER-DRIER.—Some systems include a low-side filter-drier (fig. 6-31) at the compressor end of the suction line. The filter-drier used in the suction line should offer little resistance to flow of the vaporized refrigerant, as the pressure difference between the pressure in the evaporator and the inlet of the compressor should be small. These filter-driers function to remove dirt, scale, and moisture from the refrigerant before it enters the compressor.

GAUGES AND THERMOMETERS.—Between the suction line stop valve and the compressor, a pressure gauge and thermometer may be provided to show the suction conditions at which the compressor is operating. The thermometer shows a higher temperature than the temperature corresponding to the suction pressure indicated on the gauge, because the refrigerant vapor is superheated during its passage from the evaporator to the compressor.

ACCUMULATORS AND OIL SEPARATORS.—Liquid refrigerant must never be allowed to enter the compressor. Liquids are noncompressible; in other words, their volume remains the same when compressed. An accumulator (fig. 6-32) is a small tank accessory; that is, a safety device designed to prevent liquid refrigerant from flowing into the suction line and into the compressor. A typical accumulator has an



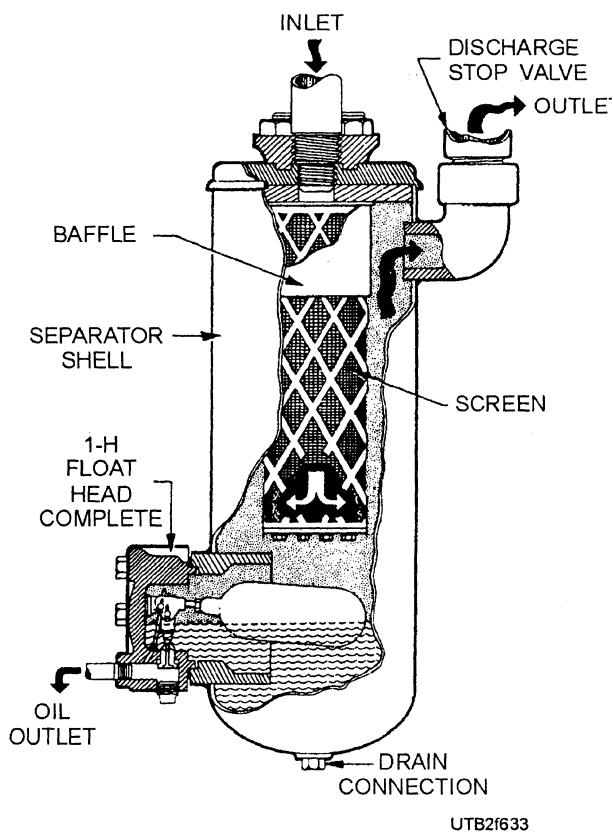


Figure 6-33.—A cutaway view of an oil separator.

Refrigerants are fluids that change their state upon the application or removal of heat within a system and, in this act of change, absorb or release heat to or from an area or substance. Many different fluids are used as refrigerants. In recent years, the most common has been air, water, ammonia, sulfur dioxide, carbon dioxide, and methylchloride.

Today, there are three specific types of refrigerants used in refrigeration and air-conditioning systems—(1) Chlorofluorocarbons or CFCs, such as R-11, R-12, and R-114; (2) Hydrochlorofluorocarbons or HCFCs, such as R-22 or R-123; and (3) Hydrofluorocarbons or HFCs, such as R-134a. All these refrigerants are "halogenated," which means they contain chlorine, fluorine, bromine, astatine, or iodine.

Refrigerants, such as Dichlorodifluoromethane (R-12), Monochlorodifluoromethane (R-22), and Refrigerant 502 (R-502), are called PRIMARY REFRIGERANTS because each one changes its state upon the application or absorption of heat, and, in this act of change, absorbs and extracts heat from the area or substance.

The primary refrigerant is so termed because it acts directly upon the area or substance, although it

may be enclosed within a system. For a primary refrigerant to cool, it must be placed in a closed system in which it can be controlled by the pressure imposed upon it. The refrigerant can then absorb at the temperature ranges desired. If a primary refrigerant were used without being controlled, it would absorb heat from most perishables and freeze them solid.

SECONDARY REFRIGERANTS are substances, such as air, water, or brine. Though hot refrigerants in themselves, they have been cooled by the primary refrigeration system; they pass over and around the areas and substances to be cooled; and they are returned with their heat load to the primary refrigeration system. Secondary refrigerants pay off where the cooling effect must be moved over a long distance and gastight lines cost too much.

Refrigerants are classified into groups. The National Refrigeration Safety Code catalogs all refrigerants into three groups—Group I – safest of the refrigerants, such as R-12, R-22, and R-502; Group II – toxic and somewhat flammable, such as R-40 (Methyl chloride) and R-764 (Sulfur dioxide); Group III – flammable refrigerants, such as R-170 (Ethane) and R-290 (Propane).

R-12 DICHLORODIFLUOROMETHANE (CCl₂F₂)

Dichlorodifluoromethane, commonly referred to as R-12, is colorless and odorless in concentrations of less than 20 percent by volume in air. In higher concentrations, its odor resembles that of carbon tetrachloride. It is nontoxic, noncorrosive, nonflammable, and has a boiling point of -21.7°F (-29°C) at atmospheric pressure.

WARNING

Because of its low-boiling point at atmospheric pressure, it prevents liquid R12 from contacting the eyes because of the possibility of freezing.

One hazard of R-12 as a refrigerant is the health risk should leakage of the vapor come into contact with an open flame of high temperature (about 1022°F) and be decomposed into phosgene gas, which is highly toxic. R-12 has a relatively low latent heat value, and, in smaller refrigerating machines, this is an advantage. R-12 is a stable compound capable of undergoing the physical changes without decomposition to which it is

commonly subjected in service. The cylinder code color for R-12 is white.

R-22 MONOCHLORODIFLUOROMETHANE (CHClF₂)

Monochlorodifluoromethane, normally called R-22, is a synthetic refrigerant developed for refrigeration systems that need a low-evaporating temperature, which explains its extensive use in household refrigerators and window air conditioners. R-22 is nontoxic, noncorrosive, nonflammable, and has a boiling point of -41°F at atmospheric pressure. R-22 can be used with reciprocating or centrifugal compressors. Water mixes readily with R-22, so larger amounts of desiccant are needed in the filter-driers to dry the refrigerant. The cylinder code color for R-22 is green.

R-502 REFRIGERANT (CHClF₂/CClF₂CF₃)

R-502 is an azeotropic mixture of 48.8 percent R-22 and 51.2 percent R-115. Azeotropic refrigerants are liquid mixtures of refrigerants that exhibit a constant maximum and minimum boiling point. These mixtures act as a single refrigerant. R-502 is noncorrosive, nonflammable, practically nontoxic, and has a boiling point of -50°F at atmospheric pressure. This refrigerant can only be used with reciprocating compressors. It is most often used in refrigeration applications for commercial frozen food equipment, such as frozen food walk-in refrigerators, frozen food display cases, and frozen food processing plants. The cylinder color code for R-502 is orchid.

R-134a TETRAFLUOROETHANE (CH₂FCF₃)

R-134a, tetrafluoroethane, is very similar to R-12, the major difference is that R-134a has no harmful influence on the ozone layer of the earth's atmosphere and is a replacement for R-12 applications. Noncorrosive, nonflammable, and nontoxic, it has a boiling point of -15°F at atmospheric pressure. Used for medium-temperature applications, such as air conditioning and commercial refrigeration, this refrigerant is now used in automobile air-conditioners. The cylinder color code for R-134a is light (sky) blue.

ADDITIONAL REFRIGERANTS

In addition to the previously mentioned refrigerants, other less common refrigerants are used in a variety of applications.

R-717 Ammonia (NH₃)

Ammonia, R-717, is commonly used in industrial systems. It has a boiling point of -28°F at atmospheric pressure. This property makes it possible to have refrigeration at temperatures considerably below zero without using pressure below atmospheric in the evaporator. Normally it is a colorless gas, is slightly flammable, and, with proper portions of air, it can form an explosive mixture, but accidents are rare. The cylinder color code for R-717 is silver.

R-125 Pentafluoroethane (CHCF₃)

Pentafluoroethane, R-125, is a blend component used in low- and medium-temperature applications. With a boiling point of -55.3°F at atmospheric pressure, R-125 is nontoxic, nonflammable, and noncorrosive. R-125 is one replacement refrigerant for R-502.

All refrigerants have their own characteristics. It is extremely important to charge a system with the refrigerant specified. Use of an incorrect refrigerant can lead to reduced efficiency, mechanical problems, and dangerous conditions.

OZONE PROTECTION AND THE CLEAN AIR ACT

Several scientific studies conducted in the 1970s showed that chlorine was a leading cause of holes in the ozone. In 1987, 30 countries signed the Montreal Protocol, which mandated the phase out of the production, and eventual use, of all harmful CFCs. In 1990, the most significant piece of legislation affecting the air conditioning and refrigeration industry, the Clean Air Act, was passed. Regulated by the Environmental Protection Agency (EPA), Title VI of the Clean Air Act states fully halogenated refrigerants (CFCs) will be phased out. It also calls for the phase out of HCFCs by the year 2030. Both of these types of refrigerants adversely affect the atmosphere, and as of July 1992, it is illegal to discharge refrigerant to the atmosphere. The production of R-12 was discontinued in December 1995, and the production of R-11, R-113, R-114, and R-115 is scheduled to be discontinued by

January 2000. Depending on the rate of depletion of the ozone layer, these timetables could be accelerated.

As a result of the Clean Air Act of 1990, there has been a determined effort by manufacturers to develop alternative refrigerants to replace those to be discontinued. CFCs, R-11, and R-12, primarily used in chillers, residential, and automotive refrigeration, can be substituted with HCFC R-123 and HFC R-134a. Future replacements include HCFC R-124 in place of CFC, R-114, in marine chillers, and HFC R-125, in place of CFC R-502, used in stores and supermarkets.

These replacement refrigerants have slightly different chemical and physical properties; thus they cannot just be "dropped" into a system designed to use CFCs. Loss of efficiency and improper operation could be the result. When changing the refrigerant in an existing system, parts of the system specifically designed to operate with a CFC refrigerant may need to be replaced or retrofitted to accommodate the new refrigerant.

Q13. What are CFCs and HCFCs?

Q14. What can happen if improper refrigerant is used in a refrigeration system?

Q15. What types of refrigerants are to be phased out by the Clean Air Act in 2030?

Q16. What refrigerant has been developed to replace R-12?

REFRIGERANT SAFETY

Learning Objective: Recall the safety requirements for handling and storage of refrigerants and refrigerant cylinders.

Safety is always paramount and this is especially true when you are working with refrigerants. Major safety concerns are discussed in this section.

PERSONAL PROTECTION

Since R-12, R-22, and R-502 are nontoxic, you will not have to wear a gas mask; however, you must protect your eyes by wearing splashproof goggles to guard against liquid refrigerant freezing the moisture of your eyes. When liquid R-12, R-22, and R-502 contact the eyes, get the injured person to the medical officer at once. Avoid rubbing or irritating the eyes. Give the following first aid immediately:

- Drop sterile mineral oil into the eyes and irrigate them.
- Wash the eyes when irrigation continues with a weak boric acid solution or a sterile salt solution not to exceed 2 percent salt.

Should the refrigerant contact the skin, flush the affected area repeatedly with water. Strip refrigerant-saturated clothing from the body, wash the skin with water, and take the patient immediately to the dispensary. Should a person be overcome in a space which lacks oxygen due to a high concentration of refrigerant, treat the victim as a person who has experienced suffocation; render assistance through artificial respiration.

HANDLING AND STORAGE OF REFRIGERANT CYLINDERS

Handling and storage of refrigerant cylinders are similar to handling and storage of any other type of compressed gas cylinders. When handling and storing cylinders, keep the following rules in mind:

- Open valves slowly; never use any tools except those approved by the manufacturer.
- Keep the cylinder cap on the cylinder unless the cylinder is in use.
- When refrigerant is discharged from a cylinder, immediately weigh the cylinder.
- Record the weight of the refrigerant remaining in the cylinder.
- Ensure only regulators and pressure gauges designed for the particular refrigerant in the cylinder are used.
- Do not use different refrigerants in the same regulator or gauges.
- Never drop cylinders or permit them to strike each other violently.
- Never use a lifting magnet or a sling. A crane may be used when a safe cradle is provided to hold the cylinders.
- Never use cylinders for any other purpose than to carry refrigerants.
- Never tamper with safety devices in the cylinder valves.
- Never force connections that do not fit. Ensure the cylinder valve outlet threads are the same as what is being connected to it.

- Never attempt to alter or repair cylinders or valves.
- Cylinders stored in the open must be protected from extremes of weather and direct sunlight. A cylinder should never be exposed to temperature above 120°F.
- Store full and empty cylinders apart to avoid confusion.
- Never store cylinders near elevators or gangways.
- Never store cylinders near highly flammable substances.
- Never expose cylinders to continuous dampness, salt water, or spray.

Q17. Goggles are not required when working with refrigerants. True/False

Q18. How often should you weigh a refrigerant cylinder?

Q19. Why are full and empty refrigerant cylinders stored separately?

REFRIGERATION EQUIPMENT

Learning Objective: Understand and recognize the basic types of commercial and domestic refrigeration equipment.

Refrigeration equipment can be classified as either self-contained or remote units. Self-contained equipment houses both the insulated storage compartments (refrigerated), in which the evaporator is located, and an uninsulated compartment (nonrefrigerated), in which the condensing unit is located, in the same cabinet. This type of equipment can be designed with a hermetically sealed, semisealed, or an open condensing unit. These units are completely assembled and charged at the factory and come ready for use with little or no installation work. Self-contained refrigerating equipment includes such equipment as domestic refrigerators and freezers, water coolers, reach-in and walk-in refrigerators, small cold-storage plants, and ice plants.

Remote refrigerating equipment has the condensing unit installed in a remote location from the main unit. These types of units are used where the heat liberated from the condenser cannot enter the space where the unit is installed or space is limited for installation.

REACH-IN REFRIGERATORS

Reach-in refrigerators have a storage capacity of 15 cubic feet or greater. At Navy installations, they are used to store perishable foods in galleys and messes. Also, at Navy hospitals and medical clinics they are used to store biologicals, serums, and other medical

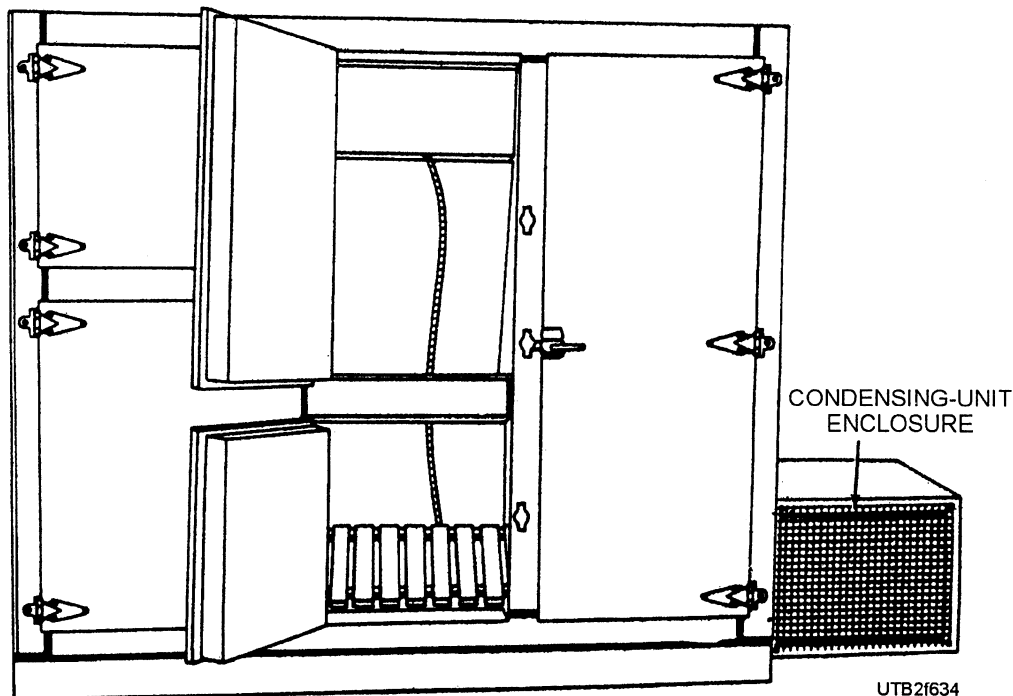
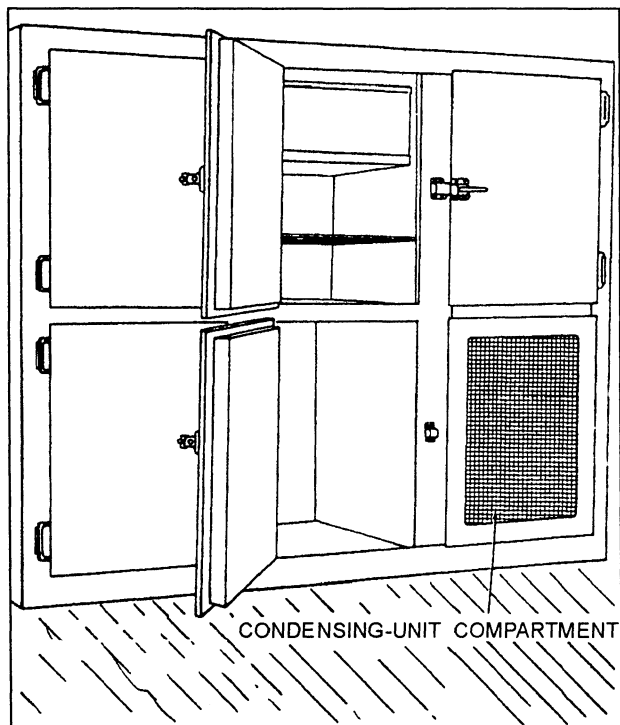


Figure 6-34.—A reach-in refrigerator with a remote condensing unit.

supplies requiring temperatures between 30°F and 45°F. Standard-size units most frequently used are those with storage capacities between 15 and 85 cubic feet. Figure 6-34 shows a typical reach-in refrigerator with a remote (detached) condensing unit.

Exterior finishes for reach-in refrigerators are usually of stainless steel, aluminum, or vinyl, while the interior finishes are usually metal or plastic, and the refrigerator cabinet is insulated with board or batten type polystyrene or urethane. Reach-in refrigerators are normally self-contained, with an air-cooled condenser, but in larger refrigerators, with remote condensers, water-cooled condensers are sometimes used. A typical self-contained unit is shown in figure 6-35. The evaporator is mounted in the center of the upper portion of the food compartment. In operation, warm air is drawn by the fan into the upper part of the unit cooler, where it passes over the evaporator coils, is cooled, and then is discharged at the bottom of the cooler. The air then passes up through the interior and around the contents of the refrigerator. The cycle is completed when the air again enters the evaporator. The low-pressure control is set to operate the evaporator on a self-defrosting cycle, and temperature is thus control led. Another type of control system uses both temperature and low-pressure control or defrost on each cycle. The evaporator fan is wired for continuous operation within the cabinet.



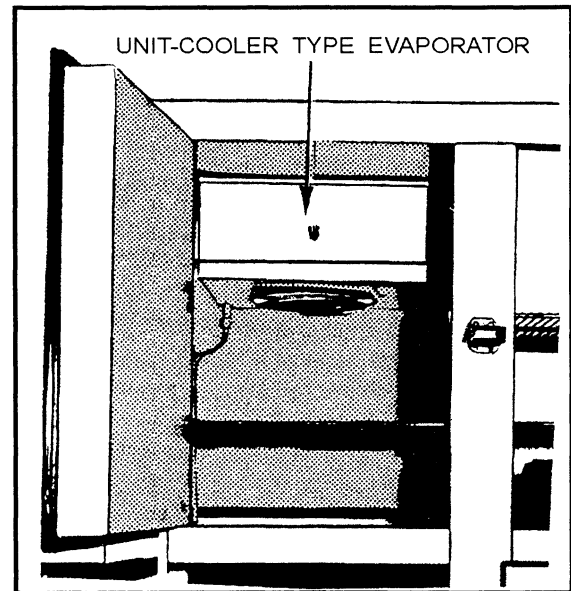
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Figure 6-35.—A self-contained reach-in refrigerator.

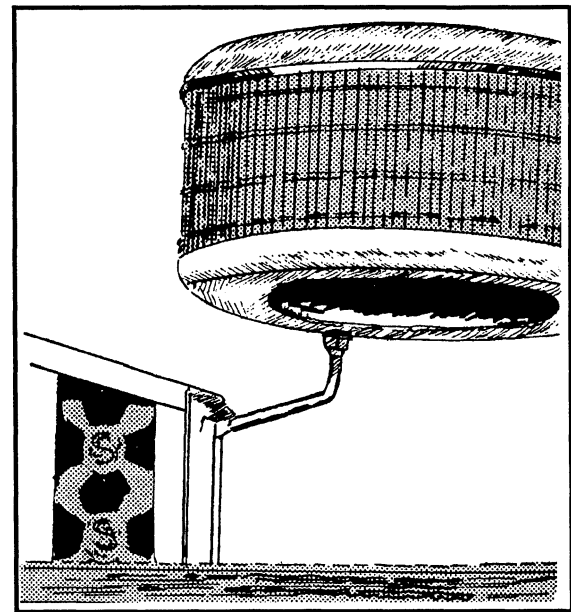
Evaporators in reach-in refrigerators are generally the unit cooler type with dry coils (fig. 6-36). In smaller capacity refrigerators, ice-making coils, similar to those used in domestic refrigerators, are often used as well as straight gravity coils. R-12 and R-502 are normally used in these units.

WALK-IN REFRIGERATORS

Walk-in refrigerators are normally larger than reach-in types and are either built-in or prefabricated sectional walk-in units. They are made in two



A



B

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Figure 6-36.—A. Unit cooler in a reach-in refrigerator; B. Dome cooler in a reach-in refrigerator.

types—one for bulk storage of fresh meats, dairy products, vegetables, and fruits requiring a temperature from 35°F to 38°F and the other for the storage of frozen food at temperatures of 10°F or below. The 35°F to 38°F refrigerators are built and shipped in sections and assembled at the location they are installed. They can be taken apart, moved, and reassembled in another area if needed. Standard-size coolers can be from 24 square feet up to 120 square feet in floor area. A walk-in refrigerator with reach-in doors is shown in figure 6-37.

The exterior and interiors of these units are normally galvanized steel or aluminum. Vinyl, porcelain, and stainless steel are also used. Most walk-in refrigerators use rigid polyurethane board, batten, or foamed insulation between the inner and outer walls. For storage temperatures between 35°F to 40°F, 3 to 4 inches of insulation is generally used. For low-temperature applications, 5 inches or more of insulation is used. These refrigerators are equipped with meat racks and hooks to store meat carcasses. Walk-in refrigerators also have a lighting system inside the refrigerator compartment. Most systems have the compressor and condenser outside the main structure and use either a wall-mounted forced-air or gravity-type evaporator that is separated from the main part of the cabinet interior by a vertical baffle.

The operation of the walk-in refrigerator is similar to that of the reach-in units. The evaporator must have

sufficient capacity (Btu per hour) to handle the heat load from infiltration and product load.

DOMESTIC REFRIGERATORS

Domestic refrigerators are used in most facilities on a Navy installation. Most domestic refrigerators are of two types—either a single door fresh food refrigerator or a two-door refrigerator-freezer combination, with the freezer compartment on the top portion of the cabinet, or a vertically split cabinet (side-by-side), with the freezer compartment on the left side of the cabinet. They are completely self-contained units and are easy to install. Most refrigerators use R-22 refrigerant, normally maintaining temperatures of 0°F in the freezer compartment and about 35°F to 45°F in the refrigerator compartment. The Utilitiesman must be able to perform various duties in the maintenance and repair of domestic refrigerators, water coolers, and ice machines at Navy activities. This section provides information to aid you in handling some of the more common types of troubles. But let us remind you that the information given here is intended as a general guide and should, therefore, be used with the manufacturer's detailed instructions. For troubleshooting guidance, see table Y in appendix II at the back of this TRAMAN.

Single Door Fresh Food Refrigerator

A single door fresh food refrigerator (fig. 6-38) consists of an evaporator placed either across the top or in one of the upper corners of the cabinet. The

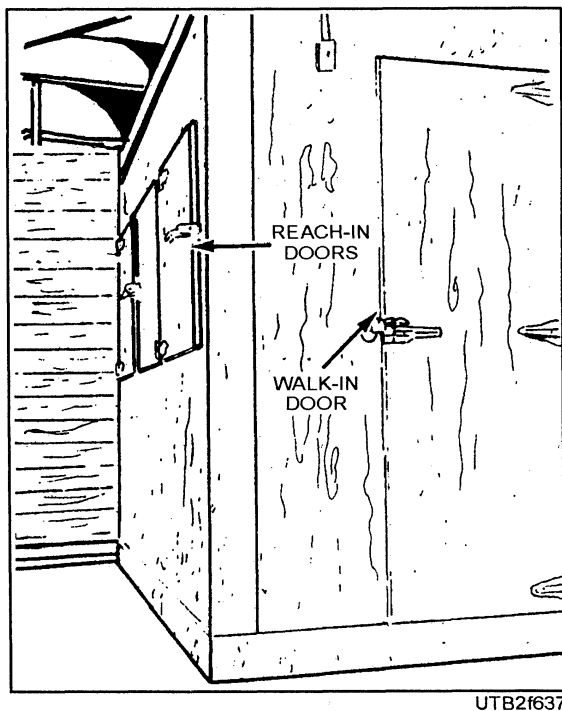


Figure 6-37.—A walk-in refrigerator with reach-in doors.

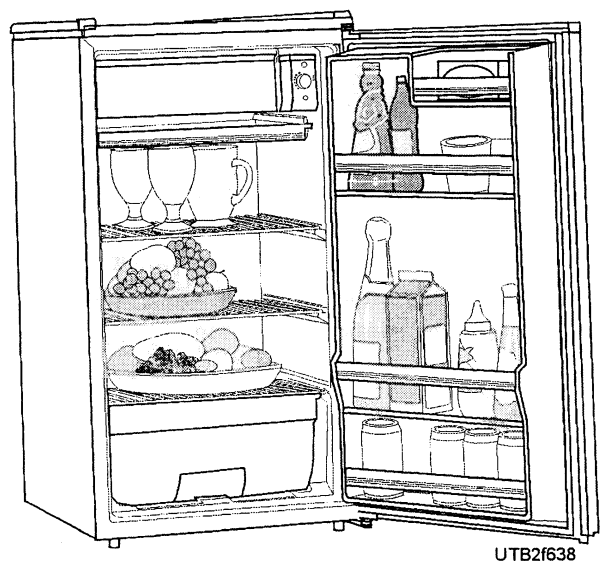


Figure 6-38.—Single door fresh food refrigerator.

condenser is on the back of the cabinet or in the bottom of the cabinet below the hermetic compressor. During operation, the cold air from the evaporator flows by natural circulation through the refrigerated space. The shelves inside the cabinet are constructed so air can circulate freely past the ends and sides, eliminating the need for a fan. This refrigerator has a manual defrost, which requires that the refrigerator be turned off periodically (usually overnight) to enable the buildup of frost on the evaporator to melt. Both the outside and inside finish is usually baked-on enamel. Porcelain enamel is found on steel cabinet liners. The interior of the unit contains the shelves, lights, thermostats, and temperature controls.

Two-Door Refrigerator-Freezer Combination

The two-door refrigerator-freezer combination is the most popular type of refrigerator. It is similar to the fresh food refrigerators in construction and the location of components except it sometimes has an evaporator for both the freezer compartment and the refrigerator compartment. Also, if it is a frost-free unit, the evaporators are on the outside of the cabinet. Because of the two separate compartments (refrigerator-freezer) and the larger capacity, these types of refrigerators use forced air (fans) to circulate the air through the inside of both compartments. The two-door refrigerator also has one of the following three types of evaporator defrost systems: manual defrost, automatic defrost, or frost-free.

There are two types of automatic defrosting: the hot gas system or the electric heater system. The hot gas system, through the use of solenoid valves, uses the heat in the vapor from the compressor discharge line and the condenser to defrost the evaporator. The other system uses electric heaters to melt the ice on the evaporator surface.

A frost-free refrigerator-freezer (fig. 6-39) has the evaporator located outside the refrigerated compartment. On the running part of the cycle, air is drawn over the evaporator and is forced into the freezer and refrigerator compartments by a fan. On the off part of the cycle, the evaporators automatically defrost.

Refrigerator-freezer cabinets are made of pressed steel with a vinyl or plastic lining on the interior wall surfaces and a lacquer exterior finish. Most domestic refrigerators have urethane foam or fiber glass insulation in the cabinet walls. The side-by-side refrigerator-freezer arrangement has a number of features not found in other refrigerators. In addition to

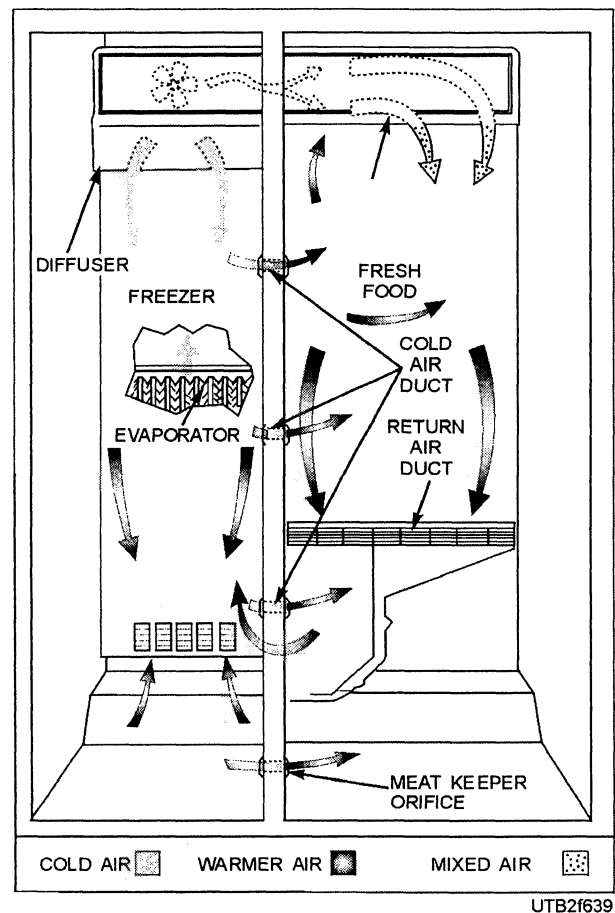


Figure 6-39.—Frost-free refrigerator airflow diagram.

the automatic icemaker in the freezer compartment, it has an option for a cold water dispenser, a cube or crushed ice dispenser, and a liquid dispenser built into the door.

WATER COOLERS AND ICE MACHINES

Water coolers provide water for drinking at a temperature under 50°F. Two types of water coolers are instantaneous and storage. The instantaneous type only cools water when it is being drawn; the storage type maintains a reservoir of cooled water. One instantaneous method used places coils in a flooded evaporator through which the water flows. A second instantaneous method uses double coils with water flowing through the inner coil with refrigerant flowing in the space between the inner coil and the outer coil. A third instantaneous method is to coil the tubing in a water storage tank. This allows refrigerant to flow through it (fig. 6-40).

Water coolers are of two basic designs—wall mounted or floor mounted. Both types are the same in construction and operation; the only difference is in the

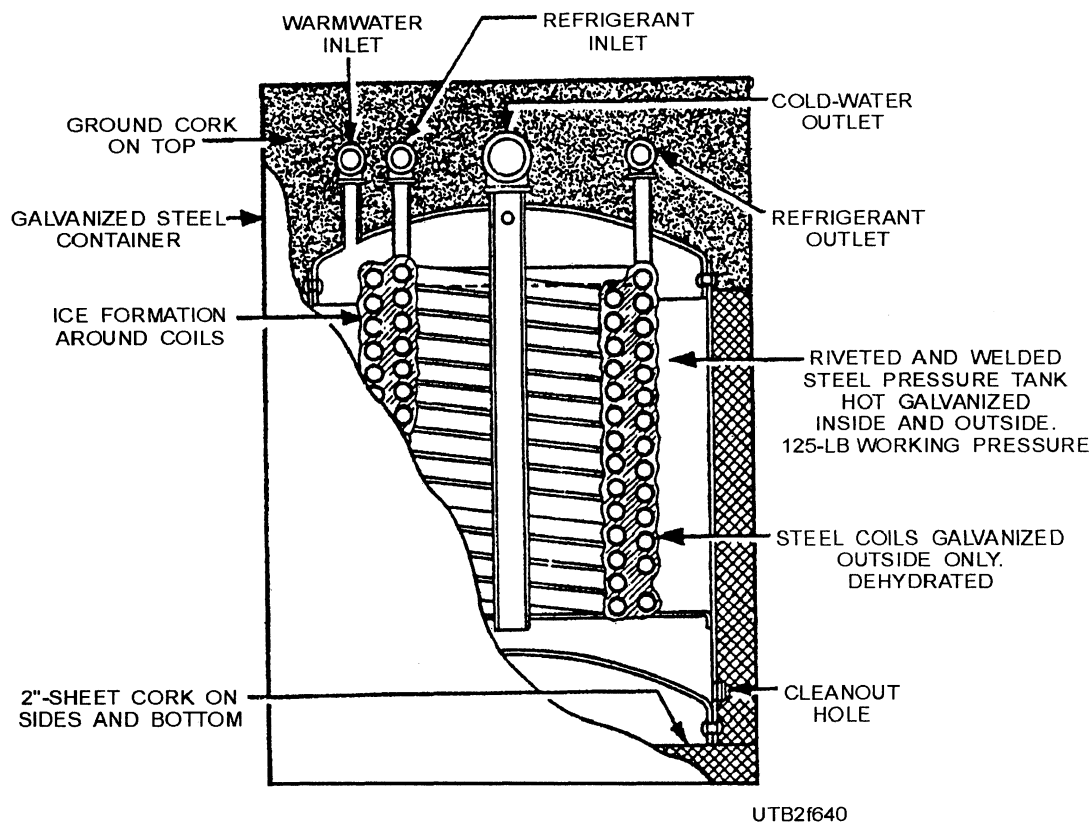


Figure 6-40.—Storage type of water cooler.

method of installation. Water cooler cabinets have a sheet metal housing attached to a steel framework. The condenser and hermetic compressor are located in the housing base, and the evaporator is located in the cabinet depending on its type of evaporator, but normally under the drain basin. Most water coolers use a heat exchanger or precooler, which precools the fresh water line to the evaporator, reducing cooling requirements for the evaporator. A thermostat, which is manually set and adjusted, is located in the cooler housing close to the evaporator.

Automatic ice machines, similar to the units shown in figures 6-41 and 6-42, are often used in galleys, barracks, gymnasiums, and other public areas. Ice machines are self-contained, automatic machines, ranging from a small unit producing 50 pounds of ice per day to a commercial unit producing 2,400 pounds of ice per day. The primary difference in the design of these machines is the evaporator. They automatically control water feed to the evaporator, freeze the water in an ice cube mold, heat the mold and empty the ice into a storage bin, and shut down when the storage bin is full. Floats and solenoids control water flow, and switches operate the storing action when ice is made. Electrical heating elements, hot water, hot gas defrosting, or mechanical devices remove the ice from the freezing

surfaces depending on the unit. Figures 6-43 and 6-44 show the freezing and defrost cycle of a typical ice cube machine. In recent years, many companies have begun to manufacture their units to use HFC R-404a refrigerant instead of HCFC R-22.

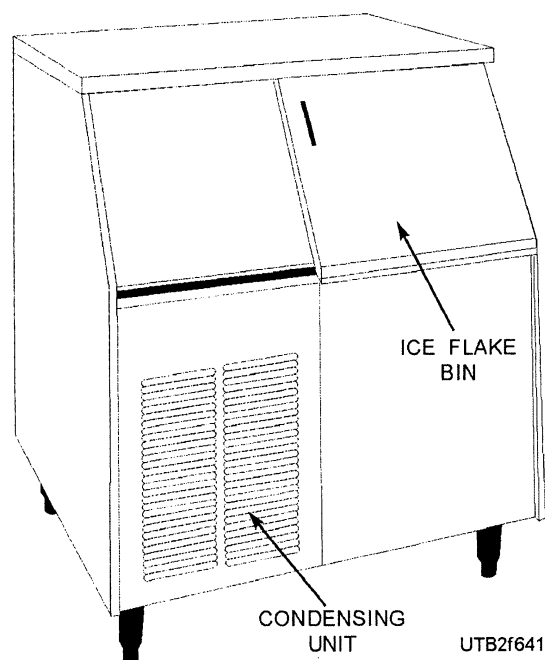


Figure 6-41.—Flake or chipped-ice machine.

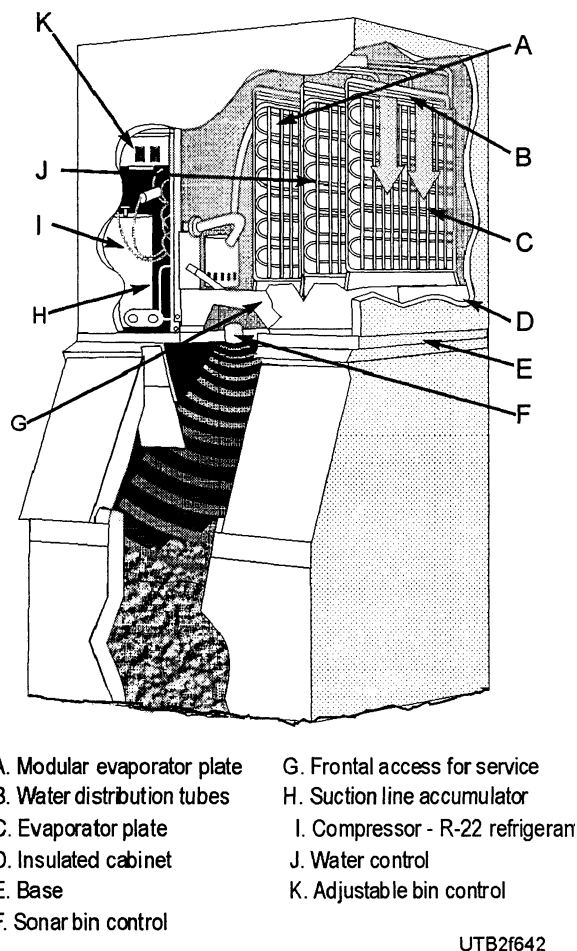


Figure 6-42.—A cutaway view of an automatic ice machine.

- Q20. What design factor makes remote refrigeration equipment different from self-contained equipment?
- Q21. Reach-in refrigerators are operated at a temperature that falls within what range, in degrees Fahrenheit?
- Q22. Reach-in refrigeration units are equipped with what type of evaporator?
- Q23. Why are walk-in refrigerators manufactured and constructed in sections?
- Q24. Domestic refrigerators come in what two design configurations?
- Q25. What are the two types of automatic defrosting in the two-door refrigerator-freezer combination unit?
- Q26. What component of a water cooler precools the fresh water line to the evaporator?

Q27. What design factor is the primary difference in the different types of ice machines?

INSTALLATION OF REFRIGERATION EQUIPMENT

Learning Objective: Recall refrigeration requirements and the types of installation for refrigeration equipment.

Utilitiesman are often tasked to installation refrigeration systems. Therefore, it is important for you to understand the basic requirements applicable to the installation of the various types of the equipment.

When installing a refrigeration or air-conditioning plant, you must not allow dirt, scale, sand, or moisture to enter any part of the refrigerant system. Since air contains moisture, its entrance into the circuit should be controlled as much as possible during installation. Most maintenance problems come from careless erection and installation. All openings to the refrigerant circuit—piping, controls, compressor, condensers, and so on—must be adequately sealed when work on them is not in progress. The R-12 refrigerant is a powerful solvent that readily dissolves foreign matter and moisture that may have entered the system during installation. This material is soon carried to the operating valves and the compressor. It becomes a distinct menace to bearings, pistons, cylinder walls, valves, and the lubricating oil. Scoring of moving parts frequently occurs when the equipment is first operated, starting with minor scratches that increase until the operation of the compressor is seriously affected.

Under existing specifications, copper tubing and copper piping needed for installation should be cleaned, deoxidized, and sealed. When there is a question about cleanliness of tubing or piping to be used, each length of pipe should be thoroughly blown out. Use a strong blast of dry air when blowing out, and clean the tubing with a cloth swab attached to copper wire pulled back and forth in the tube until it is clean and shiny. Then the ends of the tubes should be sealed until connected to the rest of the system.

EFFECTS OF MOISTURE

As little as 15 to 20 parts of moisture per million parts of R-12 can cause severe corrosion in a system. The corrosion results from hydrochloric acid formed by R-12 in contact with water. A chemical reaction takes place between the acid and the iron and copper in

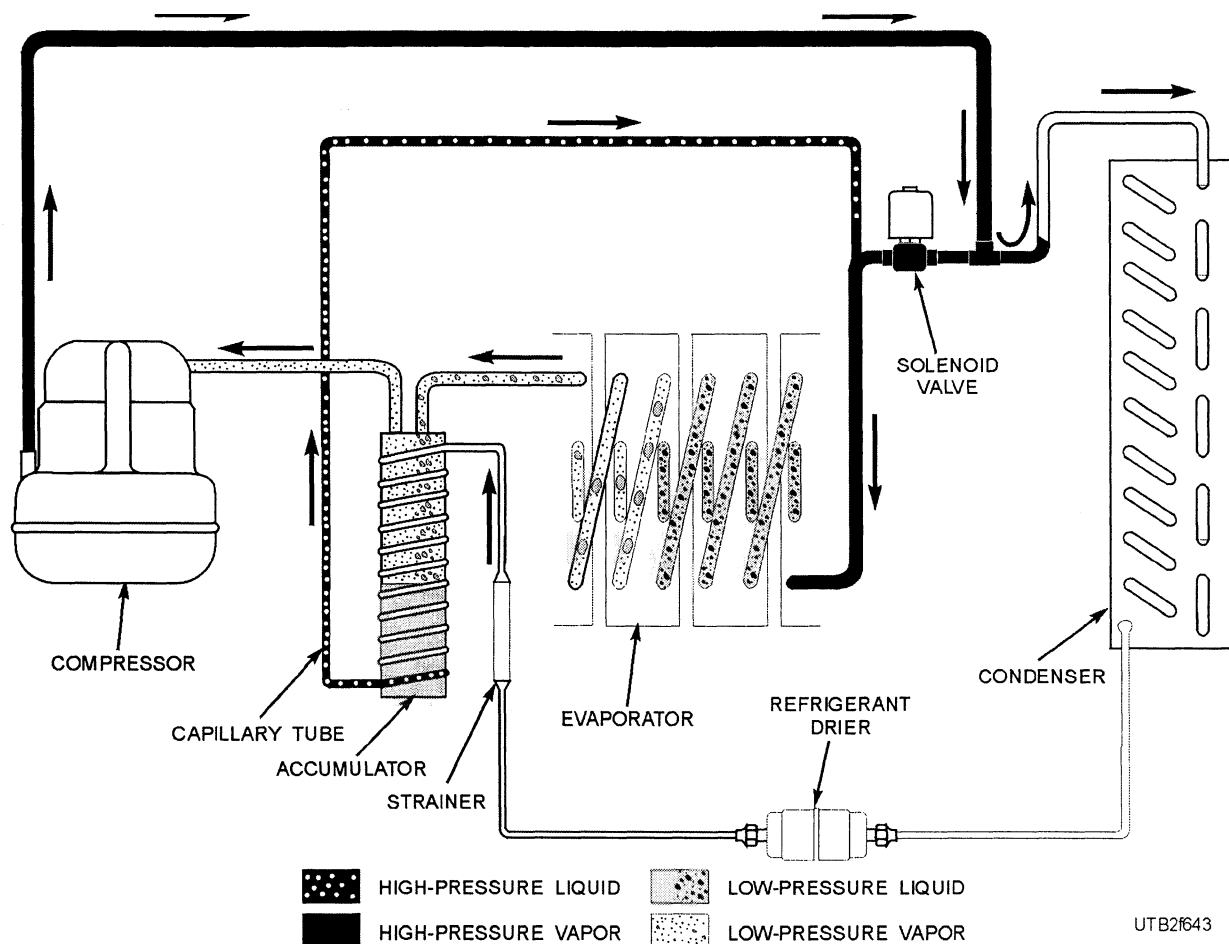


Figure 6-43.—An ice cube machine refrigeration cycle during the freezing process.

the system to form corrosion products. A strong acid combined with high discharge and compressor temperature can cause decomposition of lubricating oil and produce a sludge of breakdown products. Either the corrosion or the oil breakdown products can plug valves, strainers, and dryers and cause a serious casualty.

NOTE: The formation of ice from a minute quantity of moisture in expansion valves and capillary tubes can occur when operating below 32°F.

LOCATION OF EQUIPMENT

Adequate space should always be left around major portions of equipment for servicing purposes; otherwise, the equipment must be moved after installation so serviceable parts are accessible (figs. 6-45 and 6-46). Compressors require overhead clearance for removal of the head, discharge valve plate, and pistons with side clearance to permit removal of the flywheel and crankshaft where necessary. Water-cooled condensers require a free

area equal to the length of the condenser at one end to provide room for cleaning tubes, installing new tubes, or removal of the condenser tube assembly. Space is needed for servicing valves and accessory equipment. Service openings and inspection panels on unitary equipment require generally at least 18 inches of clearance for removal of the panel. Air-cooled condensing units should be placed in a location that permits unrestricted flow of air for condensing, whether the condenser is in a unitary piece of equipment or separate. Inadequate ventilation around air-cooled condensers can cause overloading of the motor and loss of capacity.

REFRIGERANT PIPING

Certain general precautions for the installation of refrigerant lines should be followed. When the receiver is above the cooling coil, the liquid line should be turned up before going down to the evaporator. This inverted loop prevents siphoning of the liquid from the receiver over into the cooling coil through an open or leaking expansion valve during compressor

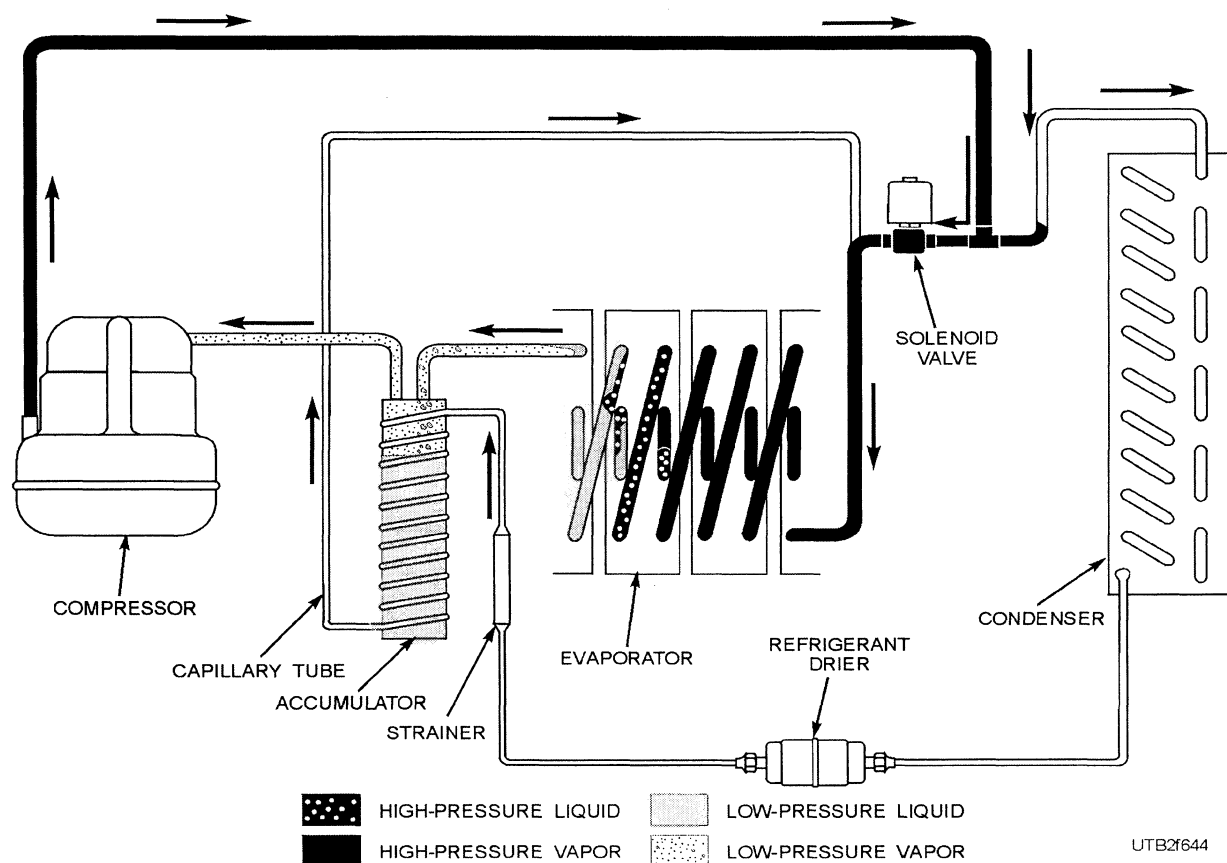


Figure 6-44.—The defrost cycle of an ice cube machine.

shutdown periods. If siphoning starts, the liquid refrigerant flashes into a gas at the top of the loop, breaking the continuity of the liquid volume and stopping the siphoning action. Where the cooling coils and compressors are on the same level, both the suction and liquid lines should be run to the overhead and then down to the condensing unit, pitching the suction line toward the compressor to ease oil return. On close-coupled installations, running both lines up to the overhead helps to eliminate vibration strains as well as provide the necessary trap at the cooling coil.

Prepare pipe and fittings with care, particularly when cutting copper tubing or pipe to prevent filings or cuttings from entering the pipe. The small particles of copper should be completely removed since the finely divided copper may pass through the suction strainer. The tube should be cut square, and all burrs and dents should be removed to prevent internal restrictions and to permit proper fit with the companion fittings. If a hacksaw is used to cut, a fine-toothed blade should be used, preferably 32 teeth per inch. The use of a hacksaw should be avoided whenever possible. When

making silver-solder joints, brighten up the ends of the tubing or pipe with a wire brush or crocus cloth to make a good bond. Do not use sandpaper, emery cloth, or steel wool for this cleansing, as this material may enter the system and cause trouble.

Acid should never be used for soldering, nor should flux be used if its residue forms an acid. Use flux sparingly so no residue will enter inside the system and eventually be washed back to the compressor crankcase. If tubing and fittings are improperly fitted because of distortion, too much flux, solder, and brazing material may enter the system.

The temperature required to solder or braze pipe joints causes oxidation within the tubing. The oxidation eventually will be removed by the refrigerant flow after the system is in operation. The oxide breaks up into a fine powder to contaminate the lubricant in the compressor and to plug strainers and driers. To eliminate this possibility, provide a neutral atmosphere within the tube being soldered or brazed. Use gas-bled nitrogen through the tubing during soldering or brazing and for a sufficient time after the



Figure 6-45.—A low-temperature screw or helix compressor system. (1) Compressor; (2) Oil separator and reservoir; (3) Oil collar; (4) Oil filters (5) Hot -gas discharge line.

bond is made until the heat of the copper has been reduced below the temperature of oxidation.

All joints should be silver-soldered and kept to a minimum to reduce leaks. Special copper tube fittings designed for refrigeration service should be used since these are manufactured with close tolerances to assure tight capillary joints in the brazing process.

SAE flare joints are generally not desired, but when necessary, care should be taken in making the joint. The flare must be of uniform thickness and should present a smooth, accurate surface, free from tool marks, splits, or scratches. The tubing must be cut square, provided with a full flare, and any burrs and saw filings removed. The flare seat of the fitting connector must be free from dents or scratches. The flare can best be made with a special swivel head flaring tool, available as a general stores item, which remains stationary and does not tear or scar the face of

the flare in the tubing. Oil should not be used on the face of the flare, either in making up the flare or in securing it to the fitting, since the oil will eventually be dissolved by the refrigerant in the system and cause a leak through the displacement of the oil. The flare joint should always be tightened with two wrenches—one to turn the nut and the other to hold the connecting piece to avoid strain on the connection and cause a leak.

Where pipe or tubing has to be bent, bends should be made with special tools designed for this type of work. Do not use rosin, sand, or any other filler inside the tubing to make a bend. Threaded joints should be coated with a special refrigerant pipe dope. In an emergency, use a thread compound for making up a joint; remember R-12 and R-22 are hydrocarbons, which dissolve any compound containing oil. A compound containing an acid or one whose residual substance forms an acid should not be used. The use of

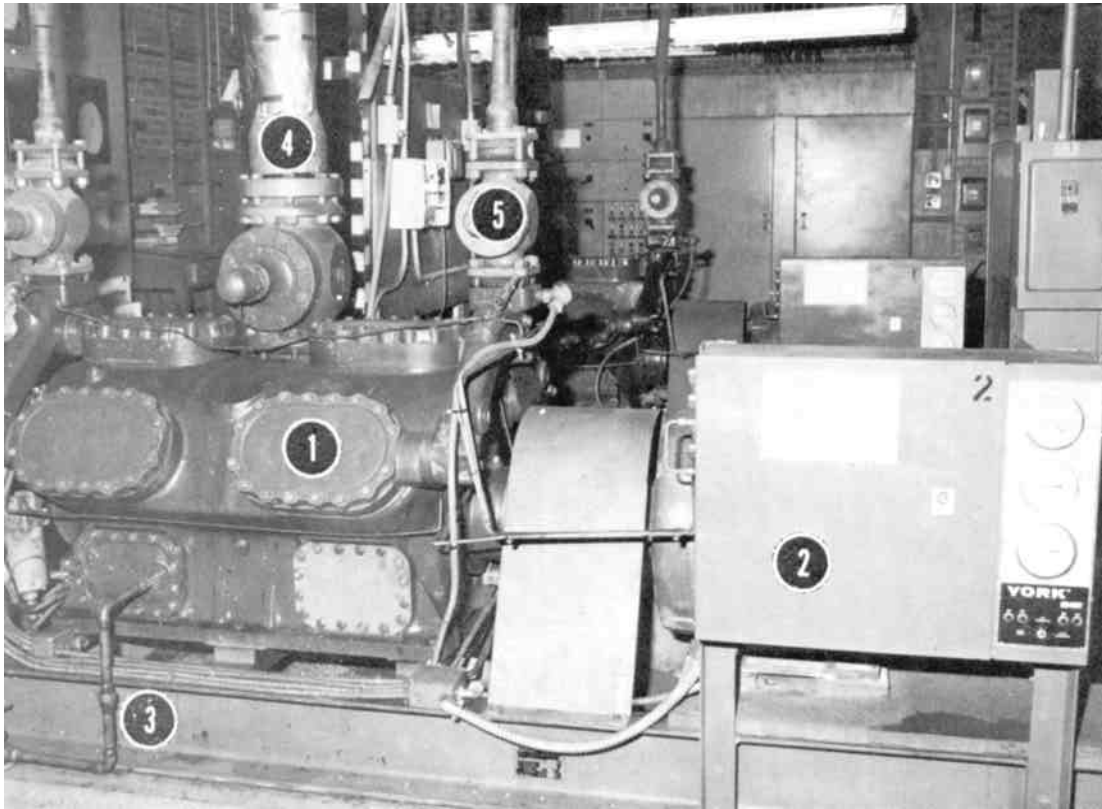


Figure 6-46.—A twelve-cylinder semihermetic reciprocating direct drive compressor. (1) Compressor; (2) control Panel; (3) Oil Return from Reservoir; (4) Suction Line; (5) Hot Gas Discharge Line.

a thick paste made of fresh lethargy and glycerin makes a satisfactory joint compound; however, the joint should be thoroughly cleaned with a solvent to eliminate oil or grease. Thread compounds should be applied to the male part of the thread after it has entered the female coupling one and one-half to two threads to prevent any excess compound from entering the system.

When securing, anchoring, or hanging the suction and liquid lines, be sure and allow enough flexibility between the compressor and the first set of hangers or points where the lines are secured to permit some degree of freedom. This flexibility relieves strain in the joints of these lines at the compressor due to compressor vibration.

MULTIPLE COMPRESSORS

Parallel operation of two or more reciprocating compressors should be avoided unless there are strong and valid reasons for not using a single compressor. In

a situation where two compressors must be used, extreme care in sizing and arranging the piping system is essential.

An acceptable arrangement of two compressors and two condensers is shown in figure 6-47. An equalizer line connects the crankcase at the oil level of each machine. Therefore, the oil in both machines will be at a common level. If machines of different sizes are used, the height of the bases beneath the machines must be adjusted so the normal oil level of both machines is at the same elevation; otherwise, the oil accumulates in the lower machine.

This arrangement is called a single-pipe crankcase equalizer. It can be used only on those machines with a single equalizer tapping entering the crankcase in such a position that the bottom of the tapping just touches the normal oil level.

Another method of piping to maintain proper oil level in two or more compressors uses two equalizer lines between the crankcase—one above the normal oil

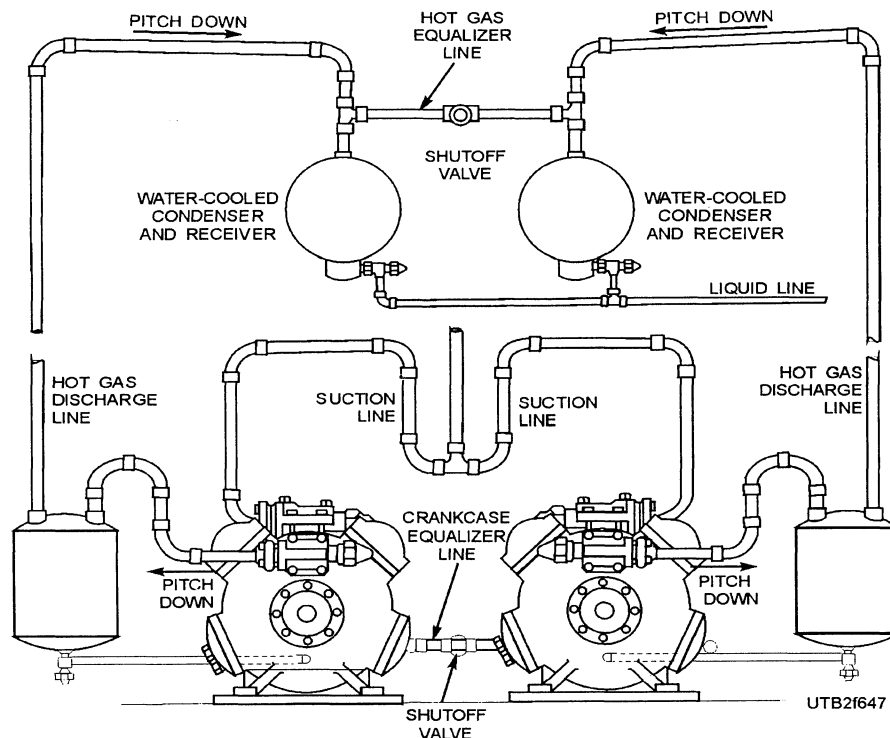


Figure 6-47.—Parallel compressors with separate condensers.

level and one below. The double equalizer system must be used on compressors having two equalizer tappings. A single equalizer line on machines having two equalizer tappings should never be used.

The lower oil equalizer line must not rise above the oil level in the crankcase and should be as level as possible. This is important since the oil builds up in one crankcase if the line rises. The upper equalizer line is a gas line intended to prevent any difference in crankcase pressure that would influence the gravity flow of oil in the lower equalizer line or the level of oil in the crankcase. This upper line must not dip, and care should be taken to eliminate pockets in which oil could accumulate to block the flow of gas. Valves in the crankcase equalizer lines are installed with the stems horizontal, so no false oil levels are created by oil rising over the valve seat and minimize flow resistance.

It is poor practice to skimp on piping when making up these equalizer lines. Oversize piping is preferred to undersize piping. General practice indicates the use of oil equalizer lines equal to the full size of the tapping in the compressor.

The discharge lines from the compressors are also equalized before they enter the condensers. This, in

effect, causes the individual condensers to function as a single unit. This is the most critical point in the piping system. It is here that pressure drop is extremely important—a pressure drop of 0.5 psi being equal to a 1.0 foot head of liquid. Excessive pressure drop in the equalizer line may rob one condenser of all liquid by forcing it into the other condenser. One of the results may be the pumping of large quantities of hot refrigerant vapor into the liquid lines from the condenser of the operating compressor. This could reduce the capacity of the system materially. For this reason, the equalizer line should be just as short and level as possible. A long equalizer line introduces an unequal pressure in condensers if one of the compressors is not operating. The refrigerant then accumulates in the condenser of the nonoperating compressor. The equalizer line should also be generously sized and should be equal to or larger than the discharge line of the largest compressor being used.

If the condensers are more than 10 feet above the compressor, U-traps or oil separators should be installed in the horizontal discharge line where it comes from each compressor.

The traps or separators prevent the oil from draining back to the compressor head on shutdown. Should a single compressor or multiple compressors with capacity modulation be used in an instance of this kind, another solution may be dictated. When a compressor unloads, less refrigerant gas is pumped through the system. The velocity of flow in the refrigerant lines drops off as the flow decreases. It is necessary to maintain gas velocities above some minimum value to keep the entrained oil moving with the refrigerant. The problem becomes particularly acute in refrigerant gas lines when the flow is upward. It does not matter whether the line is on the suction or discharge side of the compressor; the velocity must not be allowed to drop too low under low refrigerant flow conditions. Knowing the minimum velocity, 1,000 feet per minute (fpm), for oil entrainment up a vertical riser and the minimum compressor capacity, the designer of the piping can overcome this problem using a double riser.

The smaller line in the double riser is designed for minimum velocity, at the minimum step, of compressor capacity. The larger line is sized to assure that the velocity in the two lines at full load is approximately the same as in the horizontal flow lines. A trap of minimum dimensions is formed at the bottom of the double-riser assembly, which collects oil at minimum load. Trapped oil then seals off the larger line so the entire flow is through the smaller line.

If an oil separator is used at the bottom of a discharge gas riser, the need for a double riser is eliminated. The oil separator will do as its name implies—separate the major part of the oil from the gas flowing to it and return the oil to the compressor crankcase. Since no oil separator is 100 percent effective, the use of an oil separator in the discharge line does not eliminate the need for double risers in the suction lines of the same system if there are vertical risers in the suction lines. When multiple compressors with individual condensers are used, the liquid lines from the condenser should join the common liquid line at a level well below the bottoms of the condensers. The low liquid line prevents gas from an "empty" condenser from entering the line because of the seal formed by the liquid from other condensers.

NOTE: A common water-regulating valve should control the condenser water supply for a multiple system using individual condensers, so each condenser receives a proportional amount of the condenser water.

Frequently, when multiple compressors are installed, only one condenser is provided. Such

installations are satisfactory only as long as all of the compressors are operating at the same suction pressure. However, several compressors may occasionally be installed which operate at different suction pressures—the pressures corresponding, of course, to the various temperatures needed for the different cooling loads. When this is the case, a separate condenser must be installed for each compressor or group of compressors operating at the same suction pressure. Each compressor, or group of compressors, operating at one suction pressure must have a complete piping system with an evaporator and condenser, separate from the remaining compressors operating at other suction pressures. Separate systems are required because the crankcase of compressors operating at different suction pressures cannot be interconnected. There is no way of equalizing the oil return to such compressors.

The suction connection to a multiple compressor system should be made through a suction manifold, as shown in figure 6-47. The suction manifold should be as short as possible and should be taken off in such a manner that any oil accumulating in the header returns equally to each machine.

Evaporative condensers can be constructed with two or more condensers built into one spray housing. This is accomplished quite simply by providing a separate condensing coil for each compressor, or a group of compressors, operating at the same suction pressure. All of the condensing coils are built into one spray housing; this provides two or more separate condensers in one condenser housing.

- Q28. What type of acid is formed when R-12 is mixed with water?*
- Q29. Air-cooled condensers should be located in areas that provide plenty of clear space around them for what reason?*
- Q30. On close-coupled systems, running refrigerant lines up to the overhead helps eliminate what problem?*
- Q31. To eliminate possible oxidation from occurring while conducting soldering or brazing operations, you should ensure what condition exists within the tube or pipe?*
- Q32. U-traps or oil separators should be installed on multiple compressor systems when the condensers are how many feet above the compressor?*

Q33. If an oil separator is used at the bottom of a discharge riser on multiple compressor applications, the need for a double riser is eliminated. True/False.

MAINTENANCE, SERVICE, AND REPAIR OF REFRIGERATION EQUIPMENT

Learning Objective: Understand different types of maintenance equipment and methods for basic maintenance, service, and repair of refrigeration systems and components.

As a Utilitiesman, you must be able to maintain, service, and repair refrigeration equipment. This phase of our discussion provides information on different jobs that you may be assigned. When information here varies from that in the latest federal or military specifications, the specifications apply. You will find the "Troubleshooting Checklist—Refrigeration Systems," which is presented in table V, appendix II, at the end of this book, helpful in locating and correcting troubles. It is not intended to be all encompassing. Manufacturers also provide instruction manuals to aid you in maintaining and servicing their equipment.

SERVICING EQUIPMENT

Repair and service work on a refrigeration system consists mainly of containing refrigerant and measuring pressures accurately. One piece of equipment is the refrigerant gauge manifold set (fig. 6-48). It consists of a 0-500 psig gauge for measuring pressure at the compressor high side, a compound gauge (0-250 psig and 0 to -30 inches of mercury) to measure the low or suction side, and valves to control admission of the refrigerant to the refrigeration system. It also has the connections and lines required to connect the test set to the system. Depending on test and service requirements, the gauge set can be connected to the low side, the high side, a source of vacuum, or a refrigerant cylinder. A swiveling hanger allows the test set to be hung easily, and the three additional blank connections allow for securing the open ends of the three lines when the gauge set is not in use. There is always a path from the low-side and high-side input to the low-side and high-side gauge (fig. 6-49).

Another important piece of equipment is the portable vacuum pump. The type listed in the Seabee

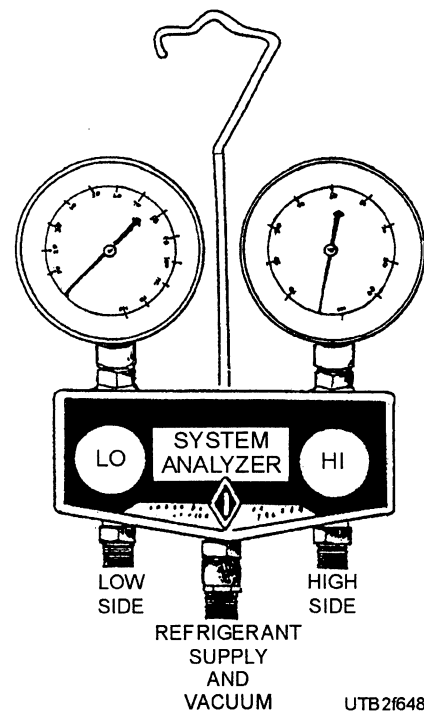


Figure 6-48.—Refrigerant gauge manifold set.

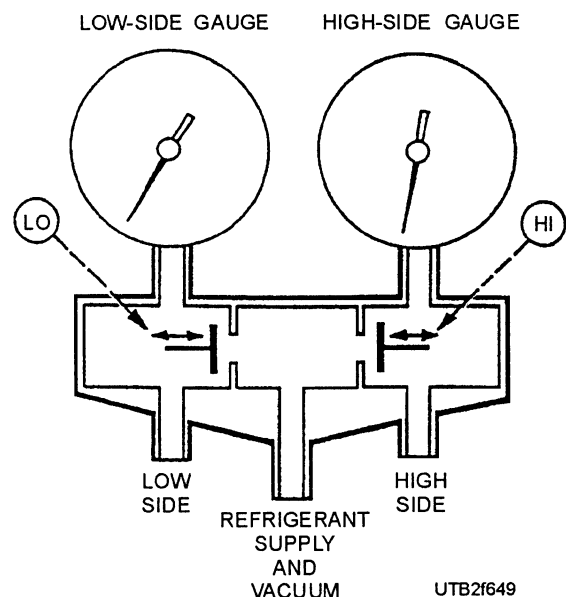


Figure 6-49.—Internal view of a refrigerant gauge manifold set.

Table of Allowance is a sealed unit consisting of a single-piston vacuum pump driven by an electric motor. A vacuum pump is the same as a compressor, except the valves are arranged so the suction valve is opened only when the suction developed by the downward stroke of the piston is greater than the vacuum already in the line. This vacuum pump can develop a vacuum close to -30 inches of mercury, which can be read on the gauge mounted on the unit

(fig. 6-50). The pump is used to reduce the pressure in a refrigeration system to below atmospheric pressure.

Various manufacturers manufacture hermetic refrigeration systems used by the Navy; therefore, the connectors and size of tubing vary. The Table of Allowance provides for a refrigeration service kit that contains several adapters, wrenches, and other materials to help connect different makes of systems to the refrigerant manifold gauge set and the vacuum pump lines. A table affixed to the lid of the storage container identifies the adapter you should use for a particular refrigeration unit.

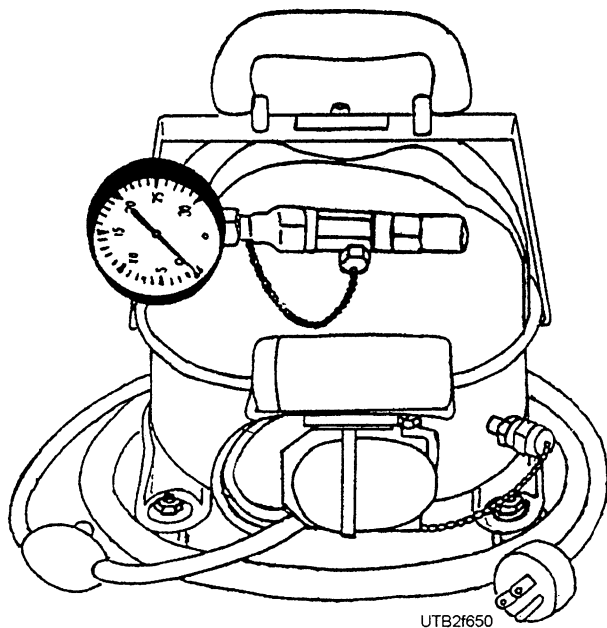


Figure 6-50.—Portable vacuum pump.

TRANSFERRING REFRIGERANTS

Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. Liquids are usually removed from the shipping containers and transferred to a service cylinder (fig. 6-51).

Before attempting transfer of refrigerants from a container to a cylinder, precool the receiving cylinder until its pressure is lower than that of the storage container or cylinder. Precool by placing the cylinder in ice water or a refrigerated tank. You must also weigh the service cylinder, including cap, and compare it with the tare weight stamped or tagged on the cylinder. The amount of refrigerant that may be placed in a cylinder is 85 percent of the tare weight (the weight of a full cylinder and its cap minus the weight of the empty cylinder and its cap).

To transfer refrigerants, connect a flexible charging line on a 1/4-inch copper tube several feet long with a circular loop about 8 to 10 inches in diameter. Be sure to install a 1/4-inch refrigerant shutoff valve (fig. 6-51) in the charging line to the service cylinder. This valve should be inserted so no more than 3 inches of tubing is between the last fitting and the valve itself. This arrangement prevents the loss of refrigerant when the service drum is finally disconnected. The entire line must be cleared of air by leaving the flare nut on the service cylinder loose and cracking the storage cylinder valve. This arrangement allows refrigerant to flow through the tubing, clearing it. After clearing, tighten the flare nut and then open the valve on the service cylinder, the valve on the

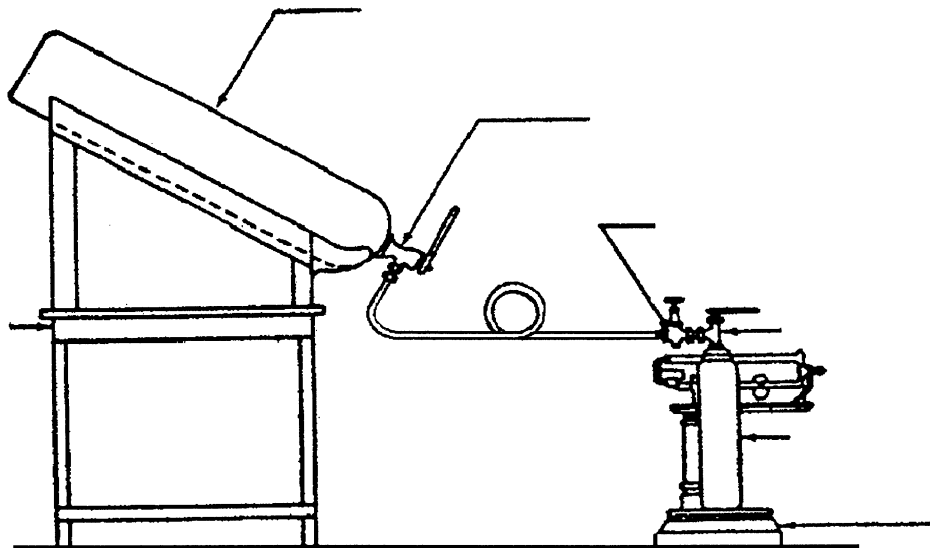


Figure 6-51.—Method of transferring refrigerants to service cylinders.

storage cylinder, and then the 1/4-inch valve in the refrigerant line. When the weight of the service cylinder shows a sufficient amount of refrigerant is in the serviced cylinder, close all valves tightly, and disconnect the charging line at the service cylinder.

CAUTION

To warm refrigerant containers or cylinders for more rapid discharge, use care to prevent a temperature above 120°F because the fusible plugs in the cylinder and valve have a melting point of about 157°F.

EVACUATING AND CHARGING A SYSTEM

One of your duties will be charging a system with refrigerant. If a system develops a leak, you must repair it first, then charge the system. Similarly, if a component of the system becomes faulty and must be replaced, some refrigerant will be lost and the system will require charging.

Evacuation

Before a system can be charged, all moisture and air must be eliminated from the components by drawing a vacuum on the system. To draw a vacuum on the system, proceed as follows:

1. Connect the portable vacuum pump to the vacuum fitting on the refrigerant manifold gauge set (fig. 6-48).
2. Connect the LO line (suction) to the suction service valve of the compressor, using appropriate connectors if required.
3. Turn the suction service valve to mid-position, so vacuum draws from the compressor crankcase and suction line back through the evaporator, expansion valve, and liquid line. When the receiver service valve, condenser service valve, and discharge service valve are open, the pump draws back through the receiver and condenser to the compressor.
4. Attach one end of a 1/4-inch copper tube to the vacuum pump discharge outlet (fig. 6-52). Allow the vacuum pump to draw a vacuum of at least 25 inches. Submerge the other end of the

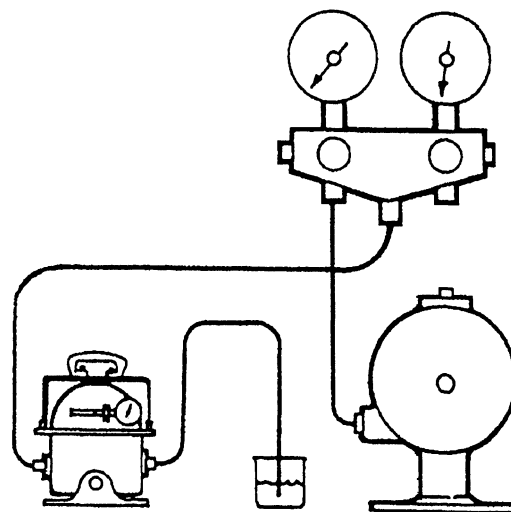


Figure 6-52.—Connections for drawing a vacuum.

copper tubing under 2 or 3 inches of clean compressor oil contained in a bottle.

5. Continue to operate the vacuum pump until there are no more bubbles of air and vapor in the oil, which indicates that a deep vacuum has been obtained.
6. Maintain the deep vacuum operation for at least 5 minutes, and then stop the vacuum pump. Leaking discharge valves of a vacuum pump cause oil to be sucked up into the copper discharge tube. Keep the vacuum pump off at least 15 minutes to allow air to enter the system through any leaks. Then start the vacuum pump. A leaky system causes bubbling of the oil in the bottle.
7. Examine and tighten any suspected joints in the line, including the line to the vacuum pump. Repeat the test.

Charging

In most small refrigerating systems, low-side charging (fig. 6-53) is generally recommended for adding refrigerant after repairs have been made. After the system has been cleaned and tested for leaks, the steps to charge the system are as follows:

1. Connect a line from a refrigerant cylinder to the bottom center connection on the refrigerant gauge manifold set. Be certain the refrigerant cylinder is in a vertical position, so only refrigerant in the form of gas, not liquid, can enter the system. Leave the connection loose and crack the valve on the cylinder. This fills

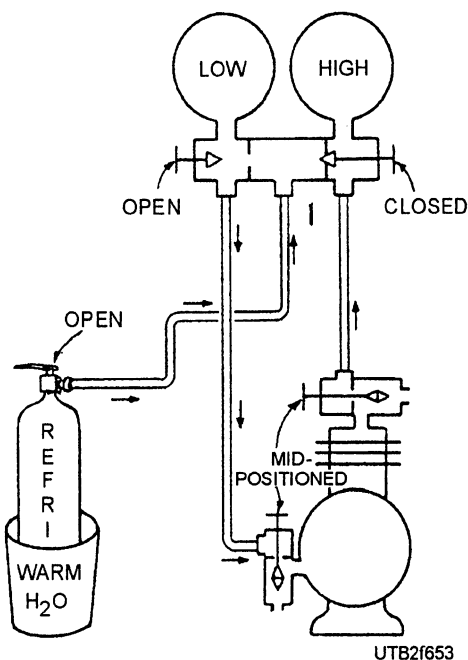


Figure 6-53.—Connections for low-side charging.

the line with gas and clears the air from the line. After clearing, tighten the connection.

2. Connect a line from the LOW (LO) valve (suction) on the gauge manifold set to the suction service valve of the compressor.
3. Start the compressor.
4. Open the valve on the cylinder and the LOW (LO) valve (suction) on the gauge manifold set.
5. Open the suction service valve on the compressor to permit the gas to enter the compressor where it will be compressed and fed to the high side. Add the refrigerant slowly and check the liquid level indicator regularly until the system is fully charged. It is easy to check the receiver refrigerant level in some makes of condensing units because the receiver has minimum and maximum liquid level indicator valves which show the height of the liquid level when opened. If a liquid line sight glass is used, the proper charge may be determined when there is no bubbling of refrigerant as it passes by the glass. The sight glass will appear empty.

Again, be certain the refrigerant cylinder is in the vertical position at all times; otherwise, the liquid refrigerant will enter the compressor and, liquid not being compressible, damage the piston or other parts of the compressor.

REFRIGERANT LEAKS

The best time to test joints and connections in a system is when there is enough pressure to increase the rate at which the refrigerant seeps from the leaking joint. There is usually enough pressure in the high-pressure side of the system; that is, in the condenser, receiver, and liquid line, including dehydrators, strainers, line valves, and solenoid valves. This is not necessarily true of the low-pressure side of the system, especially if it is a low-pressure installation, such as for frozen foods and ice cream, where pressures may run only slightly above zero on the gauge. When there is little pressure, increase the pressure in the low-pressure side of the system by bypassing the discharging pressure from the condenser to the low-pressure side through the service gauge manifold. Small leaks cannot be found unless the pressure inside the system is at least 40 to 50 psi, regardless of the method used to test for leaks.

Halide Leak Detector

The use of a halide leak detector (fig. 6-54) is the most positive method of detecting leaks in a refrigerant system using halogen refrigerants (R-12, R-22, R-11, R-502, etc.). Such a detector consists essentially of a torch burner, a copper reactor plate, and a rubber exploring hose.

Detectors use acetylene gas, alcohol, or propane as a fuel. A pump supplies the pressure for a detector that uses alcohol. If a pump-pressure type of alcohol-burning detector is used, be sure that the air pumped into the fuel tank is clean.

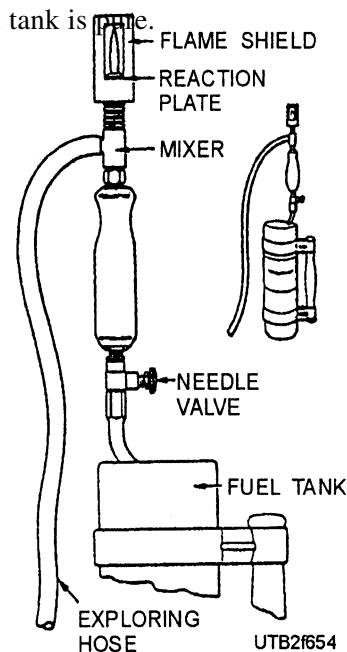


Figure 6-54.—Halide leak detector.

An atmosphere suspected of containing a halogen vapor is drawn through the rubber exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of a halogen refrigerant present, the color of the torch flame changes from blue (neutral) to green as the halogen refrigerant contacts the reactor plate. The shade of green depends upon the amount of halogen refrigerant; a pale green color shows a small concentration and a darker green color, a heavier concentration. Too much of a halogen refrigerant causes the flame to burn with a vivid purple color. Extreme concentrations of a halogen refrigerant may extinguish the flame by crowding out the oxygen available from the air.

Normally, a halide leak detector is used for R-12 and R-22 systems. In testing for leaks always start at the highest point of the system and work towards the lowest point because halogen refrigerants are heavier than air.

When using a leak detector, you will obtain the best results by following the Precautions listed below.

1. Be sure the reactor plate is properly in place.
2. Adjust the flame so it does not extend beyond the end of the burner. (A small flame is more sensitive than a large flame. If it is hard to light the torch when it is adjusted to produce a small flame, block the end of the exploring hose until the fuel ignites; then gradually open the hose.)
3. Clean out the rubber exploring hose if the flame continues to have a white or yellow color. (A white or yellow flame is an indication that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; this check can be made from time to time by holding the end of the hose to your ear.
5. Hold the end of the exploring hose close to the joint being tested to prevent dilution of the sample by stray air currents.
6. Move the end of the exploring hose slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring hose and the moment it reaches the reactor plate; permit enough time for the sample to reach the reactor plate.)

If a greenish flame is noted, repeat the test in the same area until the source of the refrigerant is located.

Always follow a definite procedure in testing for refrigerant leaks, so none of the joints are missed. Even the smallest leaks are important. However slight a leak may seem, it eventually empties the system of its charge and causes faulty operation. In the long run, the extra time spent in testing each joint will be justified. A refrigerant system should never be recharged until all leaks are discovered and repaired.

Electronic Leak Detector

The most sensitive leak detector of all is the electronic type. The principle of operation is based on the dielectric difference of gases. In operation, the gun is turned on and adjusted in a normal atmosphere. The leak-detecting probe is then passed around the surfaces suspected of leaking. If there is a leak, no matter how tiny, the halogenated refrigerant is drawn into the probe. The leak gun then gives out a piercing sound, or a light flashes, or both, because the new gas changes the resistance in the circuit.

When using an electronic leak detector, minimize drafts by shutting off fans or other devices that cause air movement. Always position the sniffer below the suspected leak. Because refrigerant is heavier than air, it drifts downward. Always remove the plastic tip and clean it before each use. Avoid clogging it with dirt and lint. Move the tip slowly around the suspected leak.

Soap and Water Test

Soap and water may be used to test for leakage of refrigerant with a pressure higher than atmospheric pressure. Make a soap and water solution by mixing a lot of soap with water to a thick consistency. Let it stand until the bubbles have disappeared, and then apply it to the suspected leaking joint with a soft brush. Wait for bubbles to appear under the clear, thick soap solution.

Find extremely small leaks by carefully examining suspected places with a strong light. If necessary, use a mirror to view the rear side of joints or other connections suspected of leaking.

PUMPING DOWN

Quality refrigeration repair includes preventing loss of refrigerant in the system. Whenever a component is removed from the system, the normally

closed system is opened and, unless precautions are taken, refrigerant is lost to the atmosphere. The best way to contain the refrigerant (gas and liquid) is to trap it in the condenser and receiver by pumping down the system.

To pump down the system, proceed as follows:

1. Secure electric power to the unit and connect the refrigerant manifold test set, as shown in figure 6-55.
2. Close the receiver stop (king) valve (by turning the valve stem inwards as far as it will go), and close both gauges on the gauge manifold (LO and HI valves).
3. Start the compressor and mid-seat the discharge and suction service valves.
4. Operate the compressor until the pressure on the suction (LO) gauge on the manifold shows a vacuum at 0 to 1 psi.
5. Stop the compressor. If the pressure rebuilds appreciably, operate the unit again until pressure registers between 0 to 1 psi. Repeat this step until the pressure no longer rebuilds appreciably.
6. When suction pressure remains at about 0 to 1 pound as read on the compound gauge, then front-seat the suction and discharge service

valves (fig. 6-56). This procedure traps practically all the refrigerant in the condenser and receiver.

RECOVERY, RECYCLING, AND RECLAIMING REFRIGERANT

Laws governing the release of chlorofluorocarbon refrigerants (CFCs) into the atmosphere have resulted in the development of procedures to recover, recycle, and reuse these refrigerants. Many companies have developed equipment necessary to prevent the release of CFCs into the atmosphere. Refrigerant recovery management equipment can be divided into three categories—recovery, recycle, and reclaiming equipment.

Recovery

Removing refrigerant from a system in any condition and storing it in an external container is called "recovery." Removal of refrigerant from the system is necessary, in some instances, when repair of a system is needed. To accomplish this, you can use special recovery equipment, which is now a requirement when removing refrigerant from a system. This equipment ensures complete removal of the refrigerant in the system.

Recovery is similar to evacuating a system with the vacuum pump and is accomplished by either the vapor recovery or liquid recovery method. In the vapor

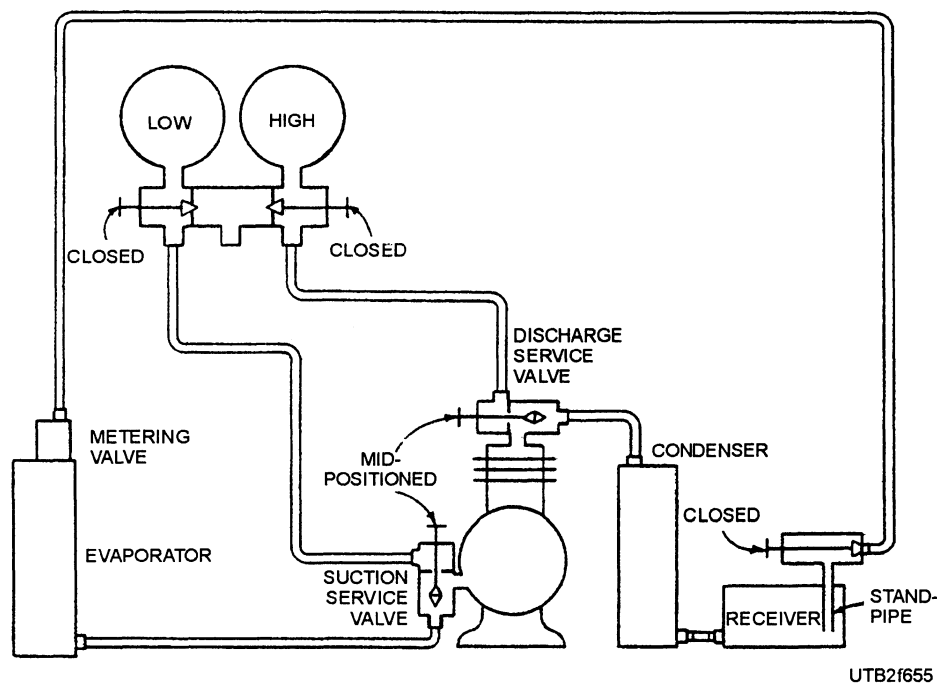


Figure 6-55.—Connections for pumping down a system.

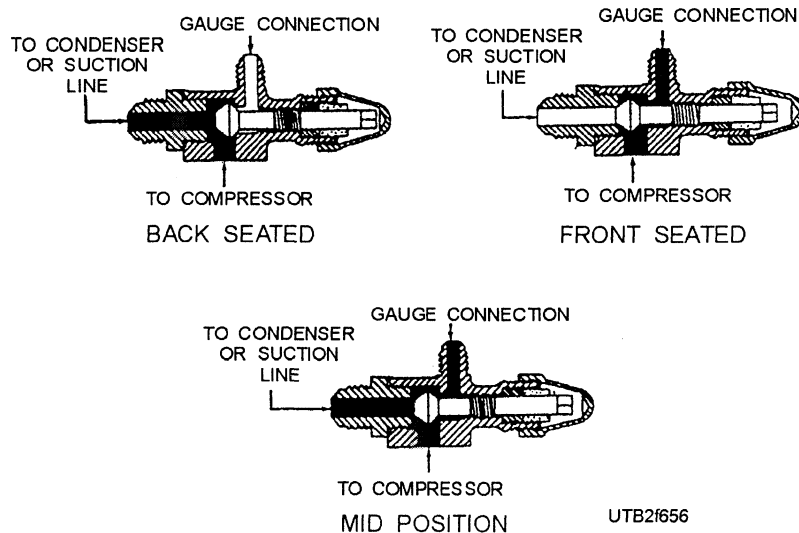


Figure 6-56.—Three-way service valve positions.

recovery method (fig. 6-57), a hose is connected to the low-side access point (compressor suction valve) through a filter-drier to the transfer unit, compressor suction valve. A hose is then connected from the transfer unit, compressor discharge valve to an external storage cylinder. When the transfer unit is turned on, it withdraws vapor refrigerant from the system into the transfer unit compressor, which, in turn, condenses the refrigerant vapor to a liquid and discharges it into the external storage cylinder.

In the liquid recovery method (fig. 6-58), a hose is connected to the low-side access point to the transfer unit compressor discharge valve. A hose is then connected from the transfer unit compressor suction valve through a filter-drier to a two-valve external storage cylinder. A third hose is connected from the

high-side access point (liquid valve at the receiver) to the two-valve external storage cylinder. When the transfer unit is turned on, the transfer unit compressor pumps refrigerant vapor from the external storage cylinder into the refrigeration system, which pressurizes it. The difference in pressure between the system and the external storage cylinder forces the liquid refrigerant from the system into the external storage cylinder. Once the liquid refrigerant is removed from the system, the remaining vapor refrigerant is removed using the vapor recovery method as previously described.

Most recovery units automatically shut off when the refrigerant has been completely recovered, but check the manufacturer's operational manual for specific instructions. You should make sure that the

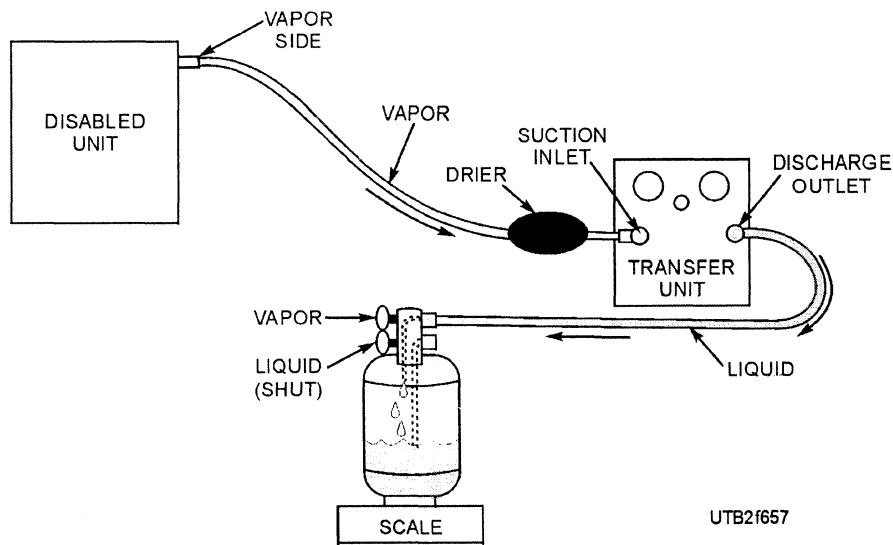


Figure 6-57.—The vapor recovery method.

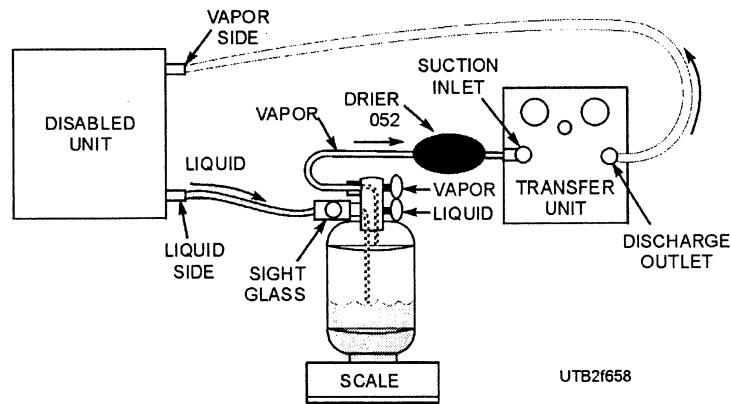


Figure 6-58.—The liquid recovery method.

external storage cylinder is not overfilled. Eighty percent capacity is normal. If the recovery unit is equipped with a sight-glass indicator, any changes that may occur should be noted.

Recycling

The process of cleaning refrigerant for reuse by oil separation and single or multiple passes through filter-driers which reduce moisture, acidity, and matter is called "recycling." In the past, refrigerant was typically vented into the atmosphere. Modern technology has developed equipment to enable reuse of old, damaged, or previously used refrigerant. Refrigerant removed from a system cannot be simply reused—it must be clean. Recycling in the field as

performed by most recycling machines reduces the contaminants through oil separation and filtration. Normally recycling is accomplished during the recovery of the vapor or liquid refrigerant by use of equipment that does both recovery and recycling of refrigerant.

Recycling machines use either the single-pass or multiple-pass method of recycling. The single-pass method (fig. 6-59) processes refrigerant through a filter-drier and/or uses distillation. It makes only one pass through the recycling process to a storage cylinder. The multiple-pass method (fig. 6-60) recirculates refrigerant through the filter-drier many times, and after a period of time or number of cycles, the refrigerant is transferred to a storage cylinder.

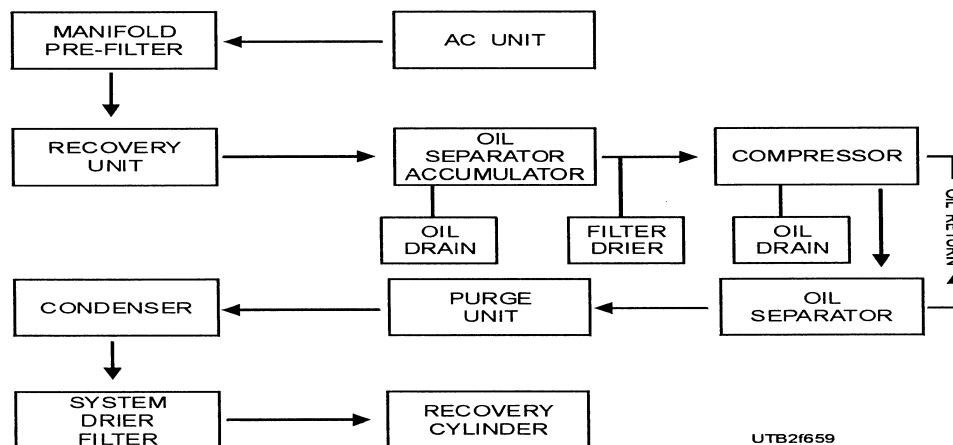


Figure 6-59.—Single-pass method of recycling.

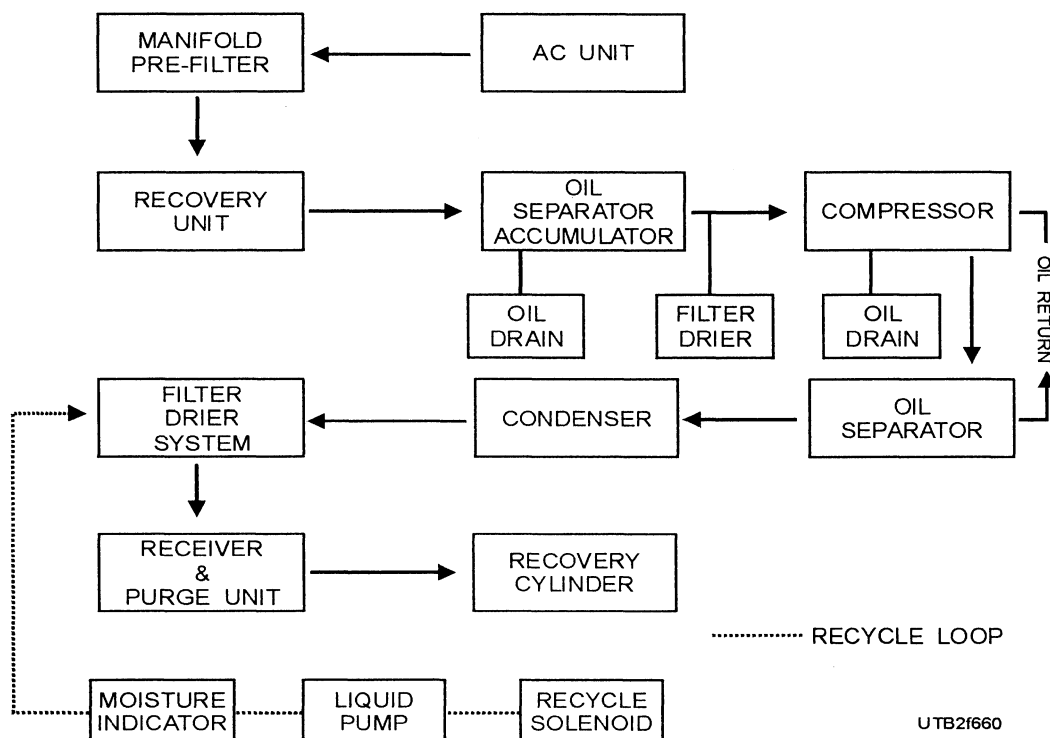


Figure 6-60.—Multiple-pass method of recycling.

Reclaiming

The reprocessing of a refrigerant to original production specifications as verified by chemical analysis is called "reclaiming." Equipment used for this process must meet SAE standards and remove 100 percent of the moisture and oil particles.

Most reclaiming equipment uses the same process cycle for reclaiming refrigerant. The refrigerant enters the unit as a vapor or liquid and is boiled violently at a high temperature at extreme high pressure (distillation). The refrigerant then enters a large, unique separator chamber where the velocity is radically reduced, which allows the high-temperature vapor to rise. During this phase all the contaminants, such as copper chips, carbon, oil, and acid, drop to the bottom of the separator to be removed during the "oil out" operation. The distilled vapor then leaves the separator and enters an air-cooled condenser where it is converted to a liquid. Then the liquid refrigerant passes through a filter-drier into a storage chamber where the refrigerant is cooled to a temperature of 38°F to 40°F by an evaporator assembly.

COMPONENT REMOVAL OR REPLACEMENT

To maintain a refrigerant system at a optimum operating condition sometimes requires removal or replacement of some component. Procedures for removal and replacement of some of the components most often requiring action are covered in this section.

Removing Expansion or Float Valves

To help ensure good results in removing expansion or float valves, you should pump the system down to a suction pressure of just over zero. You should do this at least three times before removing the expansion valve. Plug the opened end of the liquid line and evaporator coil to prevent air from entering the system. Repair or replace the expansion valve and connect it to the liquid valve. Crack the receiver service valve to clear air from the liquid line and the expansion valve. Connect the expansion valve to the evaporator coil inlet and tighten the connection. Pump a vacuum into the low side of the system to remove any air.

Replacing an Evaporator

To replace an evaporator, pump down the system and disconnect the liquid and suction lines. Then remove the expansion valve and the evaporator. Make the necessary repairs or install a new evaporator as required. Replace the expansion valve and connect the liquid and suction lines. Remove moisture and air by evacuating the system. When the evaporator is back in place, pump a deep vacuum as in starting a new installation for the first time. Check for leaks and correct them if they occur. If leaks do occur, be certain to repair them; then pump the system into a deep vacuum. Repeat the process until no more leaks are found.

Removing the Compressor

Using the gauge manifold and a vacuum pump, pump down the system. Most of the refrigerant will be trapped in the condenser and the receiver. To remove the compressor from service, proceed as follows:

1. Once the pump down is complete, the suction valve should already be closed and the suction gauge should read a vacuum. Mid-seat the discharge service valve. Open both manifold valves to allow high-pressure vapor to build up the compressor crankcase pressure to 0 psi.
2. Front-seat (close) the discharge service valve. Then crack the suction service valve until the compound gauge reads 0 to 1 psi to equalize the pressures and then front-seat the valve.
3. Joints should be cleaned with a grease solvent and dried before opening. Unbolt the suction service and discharge service valves from the compressor. DO NOT remove the suction or discharge lines from the compressor service valves.
4. Immediately plug all openings through which refrigerant flows using dry rubber, "cork" stoppers, or tape.
5. Disconnect the bolts that hold the compressor to the base and remove the drive belt or disconnect the drive coupling. You can now remove the compressor.

Removing Hermetic Compressors

Systems using hermetic compressors are not easily repaired, as most of the maintenance performed on them consists of removal and replacement.

1. Disconnect the electrical circuit including the overload switch.
2. Install a gauge manifold. Use a piercing valve (Schraider) if needed.
3. Remove the refrigerant using an EPA approved recovery/recycling unit.
4. Disconnect the suction and discharge lines. Using a pinching tool, pinch the tubing on both the suction and discharge lines, and cut both lines between the compressor and the pinched area.
5. Disconnect the bolts holding the compressor to the base and remove the compressor.

Do not forget to pump down the system and equalize the suction and head pressure to the atmosphere, if applicable. Wear goggles to prevent refrigerant from getting in your eyes. After replacement, the procedures given for removing air and moisture and recharging the system can be followed; however, the procedures may have to be modified because of the lack of some valves and connections. Follow the specific procedures contained in the manufacturer's manual.

- Q34. What are the two major pieces of maintenance equipment used for refrigeration work?*
- Q35. Before attempting transfer of refrigerant from a container to a cylinder, you should precool the receiving cylinder for what reason?*
- Q36. What is the purpose of evacuating a refrigeration system?*
- Q37. You should continue to operate the vacuum pump during evacuation of a system until what condition is obtained?*
- Q38. What method of charging a system is generally recommended?*
- Q39. What are the three methods used to detect refrigerant leaks?*
- Q40. When you pump down a system, where is the refrigerant stored?*

Q41. What are the two methods of refrigerant recovery?

Q42. Recycling refrigerant reduces contaminants through what two processes?

MAINTENANCE OF COMPRESSORS

Learning Objective: Recall the inspection points for open-type compressors and repair procedures for common problems in open-type refrigeration compressors.

Inspection points for open-type compressors and repair procedures for common problems in open-type refrigeration compressors are covered in this section.

OPEN TYPES OF COMPRESSORS

Figure 6-61 shows a vertical single-acting reciprocating compressor. Some of the duties you may perform in maintaining this and other open-type compressors are discussed below.

Shaft Bellows Seal

Refrigerant leakage often occurs at the shaft bellows seal with consequent loss of charge. Install a

test gauge in the line leading from the drum to the compressor. Attach a refrigerant drum to the suction end of the shutoff valve outlet port. Apply the proper amount of pressure, as recommended in the manufacturer's instructions. Test for leaks with a halide leak detector around the compressor shaft, seal gasket, and seal nut. Slowly turn the shaft by hand. When a leak is located at the seal nut, replace the seal plate, gasket, and seal assembly; when the leak is at the gasket, replace the gasket only. Retest the seal after reassembly. (This procedure is typical for most shaft seals on reciprocating open-type compressors.)

Valve Obstructions

Obstructions, such as dirt or corrosion, may be formed under seats of suction or discharge valves. To locate the source of trouble, proceed as follows:

When the suction side is obstructed, the unit tends to run continuously or over long periods. Connect the gauge manifold and start the unit. This pressure gauge (HI) will not indicate an increase in pressure. The low-side gauge (LO) will fluctuate and will not indicate any decrease in pressure. Clean out any obstructions and recheck again by using the test gauge assembly.

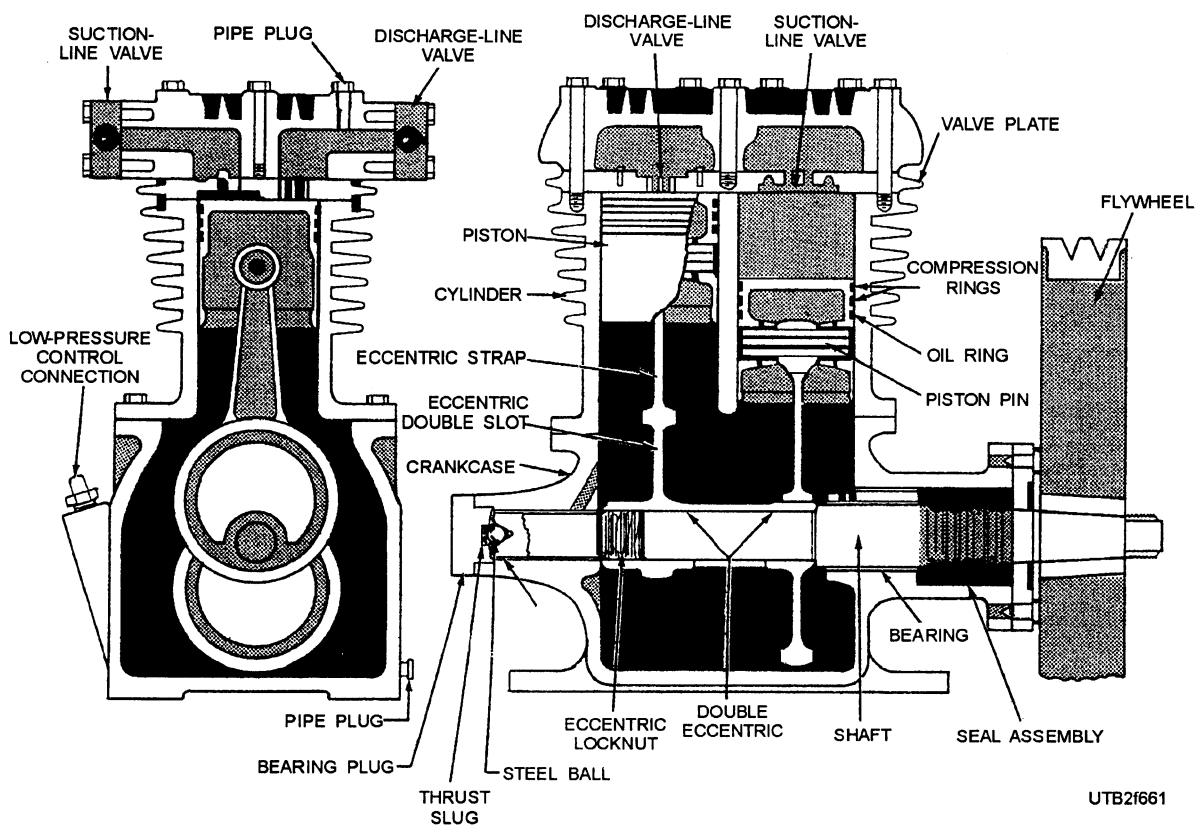


Figure 6-61.—Vertical single-acting reciprocating compressor.

To determine if there is a discharge valve leak, connect the gauge manifold and start the unit. Run it until the low-side (LO) pressure gauge indicates normal pressure for the unit. Stop the unit. With an ear near the compressor housing, listen for a hissing sound. Also, watch the gauges. When leaking caused by an obstruction is present, the low-side pressure rises, and the high side decreases until the pressures are equalized. A quick equalization of pressures indicates a bad leak that should be repaired immediately or the compressor replaced.

Compressor Lubrication

The oil level in the compressor crankcase should be checked by the procedure in the following manufacturer's manual. This procedure normally includes the following steps:

1. Attach the gauge manifold to the suction and discharge service valves.
2. Pump the system down.
3. Close the suction and discharge valves, isolating the compressor.
4. Remove the oil filter plug and measure the oil level as per the manufacturer's manual.

Compressor Knocks

When the compressor knocks, you may have to disassemble the compressor to determine whether the cause is a loose connecting rod, piston pin, or crankshaft. Sometimes a loose piston can be detected without the complete disassembly. In cases requiring disassembly, you should take the following steps:

First, remove the cylinder head and valve plate to expose the top of the piston. Start the motor and press down with your finger on top of the piston. Any looseness can be felt at each stroke. The loose part should be replaced.

Check the oil level because oil levels that are too high often cause knocks. Always make sure that a low oil level is actually the result of a lack of oil, rather than a low charge.

Stuck or Tight Compressor

A stuck or tight compressor often occurs as a result of poor reassembly after a breakdown repair. In such cases, determine where the binding occurs and

reassemble the unit with correct tolerances; avoid uneven tightening of screws or seal covers.

INSPECTION OF COMPRESSORS

An inspection should be performed on a refrigeration unit from time to time for knocks, thumps, rattles, and so on, while the unit is in operation. When any of the external parts have excessive grease, dirt, or lint, they should be cleaned. Before cleaning, you should always ensure the power is off.

A careful check of the entire system with instruments or tools is essential to determine if there has been any loss of refrigerant. **NO LEAK IS TOO SMALL TO BE FIXED.** Each leak must be stopped immediately.

Some specific conditions to look for during the inspection of a refrigeration system are as follows:

Inadequate lubrication of bearings and other moving parts.

Rusty or corroded parts discovered during the inspection should be cleaned and painted.

Hissing sounds at the expansion valve, low readings on the discharge pressure gauge, and bubbles in the receiver sight glass, all indicate a weak refrigerant charge.

Loose connections and worn or pitted switch contacts result in inoperative equipment or reduced reliability. Thermostats with burned contacts may produce abnormal temperatures in the cooled compartment.

Fans difficult to rotate by hand, with bent blades, or loose or worn belts are a source of trouble easy to locate and correct during inspection.

Air filters clogged with dirt should be cleaned or replaced during the inspection.

Hermetically sealed units should be inspected for signs of leaks and high temperatures and for too much noise or vibration.

Q43. On compressors, refrigerant leaks most often occur at what location?

Q44. Hissing sounds at the expansion valves, low discharge pressure, and bubbles in the receiver sight glass during inspections indicate what possible problems?

Q45. When inspecting hermetic compressors, you should look for what type of problems?

MAINTENANCE OF MOTORS

Learning Objective: Understand basic maintenance of motors and methods of electrical troubleshooting of motors.

Troubles with the electrical motors used to drive the compressors of mechanical refrigeration systems fall into two classes—mechanical and electrical.

MECHANICAL PROBLEMS

Some compressors are belt-driven from the electrical motor. For proper operation, both the belt tension and pulley alignment adjustments must be made. Belt tension should be adjusted so a 1-pound force on the center of the belt, either up or down, does not depress it more than one-half inch. To adjust the alignment, loosen the setscrew on the motor pulley after tension adjustment is made. Be sure the pulley turns freely on the shaft; add a little oil if necessary. Turn the flywheel forward and backward several times. When it is correctly aligned, the pulley does not move inward or outward on the motor shaft. Tighten the setscrew holding the pulley to the shaft before starting the motor.

Compressors may also be driven directly by a mechanical coupling between the motor and compressor shafts. Be sure the two shafts are positioned so they form a straight line with each other. The coupling on direct drive units should be realigned after repair or replacement. Clamp a dial indicator to the motor half coupling with its pointer against the outer edge of the compressor half coupling. Rotate the motor shaft, and observe any fluctuations of the indicator. Move the motor or compressor until the indicator is stationary when revolving the shaft one full turn. Secure the hold-down bolts and then recheck.

Moisture in the System

When liquid refrigerant that contains moisture vaporizes, the moisture separates from the vapor. Because the vaporization of the refrigerant causes a cooling effect, the water that has separated can freeze. Most of the expansion and vaporization of the refrigerant occurs in the evaporator. However, a small amount of the liquid refrigerant vaporizes in the expansion valve, and the valve is cooled below the

freezing point of water. As a result, ice can form in the expansion valve and interfere with its operation. If the needle in the valve freezes in a slightly off-seat position, the valve cannot permit the passage of enough refrigerant. If the needle freezes in a position far from the seat, the valve feeds too much refrigerant. In either case, precautions must be observed to assure a moisture-free system.

A dehydrator is filled with a chemical known as a desiccant, which absorbs moisture from the refrigerant passing through the dehydrator. Dehydrators are installed in the liquid line to absorb moisture in the system after the original installation. An arrow on the dehydrator indicates the direction of flow. Desiccants are granular and are composed of silica gel, activated alumina, or calcium sulfate. Do not use calcium chloride or chemicals that form a nonfreezing solution. These solutions may react with moisture to form undesirable substances, such as gums, sludges, or waxes. Follow the manufacturer's instructions as to limitations of dehydrators, as well as operation, recharging, replacing, and servicing.

Loose Copper Tubing

In sealed units, loose copper tubing is usually detected by the sound of rattling or metallic vibration. Bending the tubing carefully to the position of least vibration usually eliminates the defect. Do not touch it against other tubing or parts at a point of free movement, and do not change the tubing pitch or the tubing diameter by careless bending.

In open units, lengths of tubing must be well supported by conduit straps or other devices attached to walls, ceilings, or fixtures. Use friction tape pads to protect the copper tubing from the metal of the strap. When two tubes are together in a parallel position, wrapping and binding them together with tape can prevent vibration. When two lines are placed in contact for heat exchange, they should be soldered to prevent rattling and to permit better heat transfer.

Doors and Hardware

When hinges must be replaced because of lack of lubrication or other reasons, the use of exact duplicates is preferable. Loose hinge pins must be securely braided. When thrust bearings are provided, they are held in place by a pin.

The latch or catch is usually adjusted for proper gasket compression. Shims or spacers may be added

Repair or replace missing, worn, warped, or loose door gaskets. If the gasket is tacked on, rustproof tacks or staples should be used. If the gasket is clamped or held in place by the doorframe or the door panel, an exact replacement is necessary. In either case, the gasket should be installed so when the door is closed a complete and uniformly tight seal results. If doors freeze closed due to condensation and subsequent freezing, apply a light coat of glycerine on the gaskets.

Cooling units in the 35°F to 45°F reach-in or walk-in refrigerators or cold storage rooms are generally defrosted automatically by setting the low-pressure control switch to a predetermined level. If this setting causes overload with consequent heavy frosting of the coil, manual defrosting is necessary. Cooling units of 35°F and lower temperatures are defrosted manually. The most common method for manual defrosting is to spray water over the cooling

ELECTRICAL DEFECTS

Opens

Figure 6-62 shows a simple refrigeration control system. You have learned the basics of electricity and how to use meters. Using this figure, you will put that knowledge to work. Remember one fact—if you are



not sure what you are doing, call your supervisor or arrange for a Construction Electrician to assist you.

An "open" is defined as the condition of a component that prevents it from passing current. It may be a broken wire, a burned or pitted relay contact, a blown fuse, a broken relay coil, or a burned-out coil winding. An open can be located in one of two ways. For the components in series, such as the main disconnect switch, fuses, the wire from Point C to Point D (fig. 6-62), the relay contacts, and the wire from Point E to Point F, a voltmeter should be used. Set up the voltmeter to measure the source voltage (120 volts ac, in this case). If the suspected component is open, the source will be measured across it. To check part of the main disconnect switch, close the switch and measure from Point A to Point B. If the meter reading is 0 volts, that part of the switch is good; if the voltage equals the source voltage, the switch is open. To check the fuse F2, measure across it, Point B to Point C. Measuring across Points C and D or E and F will check the connecting wires for opens. One set of relay contacts can be checked by taking meter readings at Points D and E. These are just a few examples, but the rule of series components can always be applied. Remember, the three sets of contacts of relay K1 will not close unless voltage is present across the relay coil; the coil cannot be open or shorted. When testing an electrical circuit, follow the safe practices you have been taught and use procedures outlined in equipment manuals.

Opens in components that are in parallel cannot easily be found with a voltmeter because, as you know, parallel components have voltage across them at all times when the circuit is energized. In figure 6-62, the branch with the motor relay K1 and the dual refrigerant pressure control are considered a parallel circuit. Because when the main disconnect switch is closed and the fuses are good, there is voltage between Points C and H, regardless of whether the relay coil and pressure switch are open. To check for opens in these components, use an ohmmeter set at a low range. Disconnect all power by opening (and locking out, if possible) the main disconnect switch. This action removes all power and ensures both personal and equipment safety. To check the motor relay K1 to see if its coil is open, put the ohmmeter leads on Points C and G. A reading near infinity (extremely high resistance) indicates an open. The contacts of the dual refrigerant pressure control can be tested by putting the ohmmeter leads from Point G to Point H. Again, a reading near infinity indicates open contacts. You may need to consult the manufacturer's manual for the

physical location of Points G and H. Notice the contacts of the control are normally closed when neither the head pressure nor the suction pressure is above its set limits.

Shorts

Shorts are just the opposite of opens. Instead of preventing the flow of current, they allow too much current to flow, often blowing fuses. The ohmmeter on its lowest range is used to locate shorts by measuring the resistance across suspected components. If the coil of the motor relay K1 is suspected of being shorted, put the leads on Points C and G. A lower than normal reading (usually almost zero) indicates a short. You may have to determine the normal reading by consulting the manufacturer's manual or by measuring the resistance of the coil of a known good relay. If fuses F2 and F3 blow and you suspect a short between the middle and bottom lines (fig. 6-62), put the ohmmeter leads between Points C and H. Again, a low reading indicates a short. Remember, in all operations using an ohmmeter, it is imperative that all power be removed from the circuit for equipment and personal safety. Don't fail to do this!

Grounds

A ground is an accidental connection between a part of an electrical circuit and ground, due perhaps, to physical contact through wearing of insulation or movement. To locate a ground, follow the same procedure you used to locate a short. The earth itself, a cold-water pipe, or the frame of a machine are all examples of ground points. To see whether a component is shorted to ground, put one ohmmeter lead on ground and the other on the point suspected to be grounded and follow the rules for locating a short. Be sure to turn off all power to the unit. It may even be wise to check for the presence of voltage first. Use a voltmeter set to the range suitable for measuring source voltage. If power does not exist, then use the ohmmeter.

The limited amount of instruction presented here is not enough to qualify you as an electrician, but it should enable you to find such troubles as blown fuses, poor electrical connections, and the like. If the trouble appears more complicated than this, call your supervisor or ask for assistance from a Construction Electrician.

Testing the Motor

As a Utilitiesman, you should be able to make voltage measurements in a refrigeration system to ensure the proper voltage is applied to the drive motor, as shown on the rating plate of the motor. If the proper voltage is applied (within 10 percent) to the terminals of the motor and yet it does not run, you must decide what to do. If it is an open system (not hermetically sealed), it is the Construction Electrician's job to repair the motor. If it is a hermetically sealed unit, however, you must use special test equipment to complete further tests and perhaps make the unit operational again.

If the unit doesn't run, it may be because the motor rotor or compressor crankshaft is stuck (remember, in a hermetically sealed unit, they are one and the same). If you apply electrical power to try and move the motor in the correct direction first and then reverse the power, you may be able to rock it free and not have to replace the unit. This is one of the purposes of the hermetic unit analyzer (fig. 6-63). To rock the rotor of an hermetically sealed unit, follow these steps:

1. Determine from the manufacturer's manual whether the motor is a split-phase or a capacitor-start type.
2. Remove any external wiring from the motor terminals.

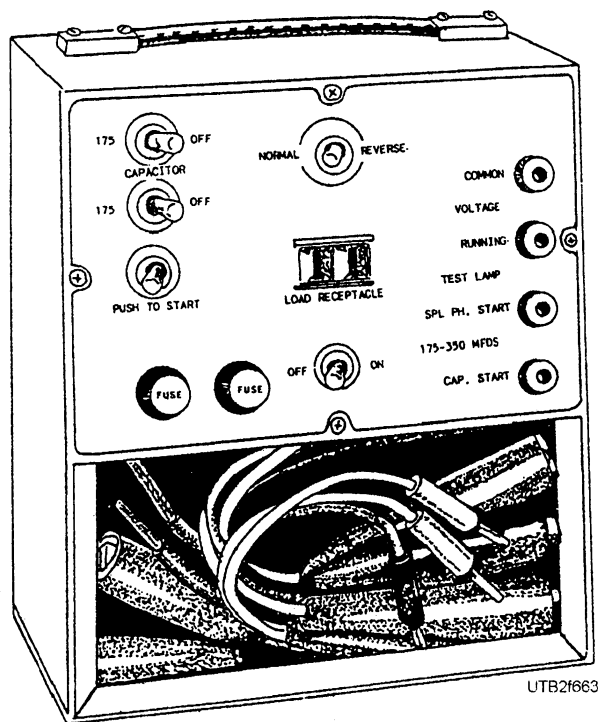


Figure 6-63.—Hermetic unit analyzer.

3. Place the analyzer plugs in the jacks of the same color. If a split-phase motor is used, put the red plug in jack No. 3; if the capacitor-start motor is used, put the red plug in jack No. 4; and select a capacity value close to the old one with the toggle switches.
4. Connect the test clips as follows:
 - White to common
 - Black to the running winding
 - Red to the starting winding
5. Hold the push-to-start button down and at the same time move the handle of the rocker switch from normal to reverse. The frequency of rocking should not exceed five times within a 15-second period. If the motor starts, be certain that the rocker switch is in the normal position before releasing the push-to-start button.
6. More tests can be made with the hermetic unit analyzer, such as testing for continuity of windings and for grounded windings. Procedures for these tests are provided in the manual that comes with the analyzer. Generally, if the rocking procedure does not result in a free and running motor, the unit must be replaced.

TROUBLESHOOTING REFRIGERATION EQUIPMENT

Troubleshooting of any type of refrigeration unit depends, in part, on your ability to compare normal operation with that obtained from the unit being operated. Obviously for you to detect these abnormal operations, you must first know what normal operation is. Climate affects running time. A refrigeration unit generally operates more efficiently in a dry climate. In an ambient temperature of 75°F, the running period usually approximates 2 to 4 minutes, and the off period, 12 to 20 minutes.

It is beyond the scope of this text to cover all of the troubles you may encounter in working with refrigeration equipment. If you apply yourself, you can acquire a lot of additional information through on-the-job training and experience and studying the manufacturer's instruction manuals.

First and foremost, safety must be stressed and safe operating practices followed before and while doing any troubleshooting or service work. All local and

national codes, as well as DoD rules concerning safety, must be observed. Some of the more important safety steps that are often overlooked are as follows:

- Protective equipment, such as eye protection, gloves, hard hats, and so forth, must be available and worn.
- Fire extinguishers must be readily available, in good working order, and adequate for the situation.
- Safety tags with such notations as "Danger," "Hands Off," "Do Not Operate," and "Do Not Throw Switch" should be attached to valves, switches, and at other strategic locations when servicing or making repairs.
- Install machinery guards properly before operating machinery.

The above is only a short list and not intended to be all-inclusive. You will also find table W, appendix II, "Troubleshooting — Industrial Refrigeration," and table Y, appendix II, "Troubleshooting — Domestic Refrigerators and Freezers," useful guides for locating and correcting different troubles in refrigeration equipment.

- Q46. *Most problems with electrical motors for refrigeration system compressors fall into what classes?*
- Q47. *How often is the coupling on the shafts of direct drive motors realigned?*
- Q48. *What piece of equipment is installed in a refrigeration system just before the expansion valve to remove moisture?*
- Q49. *Manually defrosting is normally required on refrigeration units that operate at what temperature?*
- Q50. *If you suspect a component is open, you should test the source in what way?*
- Q51. *What unit of measurement on a multimeter do you use to test for a short?*
- Q52. *When checking for a ground, you use the same troubleshooting procedure as used for what other problem?*
- Q53. *Troubleshooting a refrigeration system depends partly on your knowledge of how the equipment runs normally. True/False.*

LOGS

Learning Objective: Understand the importance and use of maintaining, operating, and inspecting logs for refrigeration equipment.

When maintaining, standing watch, operating, or inspecting refrigerating and air-conditioning equipment, the Utilitiesman may be responsible for keeping operation, inspection, or maintenance logs on the equipment. Try to keep the logs neat and clean. You must ensure that any information recorded in them is accurate and legible.

Operation and maintenance logs may help to spot trouble in the equipment. They also aid in ensuring proper periodic maintenance and inspection are performed on the equipment. Logs may provide a means of self-protection when trouble occurs and the cause can be placed on an individual.

Good judgment must always be used in analysis of service troubles and specific corrections should be followed whenever possible. One of the methods for determining when and what corrective measures are necessary on equipment or a plant which is not operating properly is to compare the pressures and temperatures of various parts of the system with corresponding readings taken in the past when the equipment or plant was operating properly under similar heat load and circulating water temperature conditions.

A typical operating log may contain entries such as the following:

- Date and time of readings
- Ambient temperature
- Suction pressure and temperature readings
- Discharge pressure and temperature readings
- Condenser pressure and temperature
- Evaporator pressure and temperature
- Oil level in the compressor
- Operating hours

These types of readings give a complete picture of the current and past operating conditions of the equipment or plant and can assist the Utilitiesman in keeping the equipment or plant at its maximum efficiency.

Maintenance logs contain entries of when, what, and who performed routine periodic maintenance on

the equipment or plant. Such logs help ensure that the equipment or plant is well maintained and that the life expectancy of the equipment or plant is fully used. These logs also can assist in determining estimates for future budget requirements for maintenance on the equipment or plant. Maintenance log entries may include the following:

- Date of maintenance
- Type of maintenance
- What was done
- Who did the work

- Cost of the work
- Materials used

It is important to compare operating log readings of the equipment or plant before the maintenance with those taken after the maintenance was completed to ensure maintenance was accomplished properly, and that it had no ill effects on the equipment or plant.

Q54. Operating and maintenance logs can assist in spotting troubles in refrigeration equipment or plants. True/False.

Q55. Maintenance logs can be used to figure future maintenance cost requirements. True /False.